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PHYSICS.—*Romance or Science?*[1]

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The text for my discourse this evening is taken from the editorial columns of the New York Times for September 18.

"Your physicist is supposed to be a hard, matter-of-fact measurer who suppresses romantic speculation and talks only of energy, volts, ions and electrons. Confront him with a mystery and he proves to be as human as the rest of us. Consider the cosmic rays. For years Millikan in this country and Kolhoerster, Hess, Regener, and others in Europe have been studying them only to their own mystification and ours. Measuring instruments are dropped into lakes a thousand feet or elevated twenty miles above sea-level. Piccard imperils his life to determine the true nature of the rays. Professor Compton and a devoted band of physicists station themselves at the Equator, in the far north, on mountain-tops, in deep mines to conduct their investigations. And the result? Romance—sheer romance.

Millikan spins a tale of electrons and protons combining in space, and of resultant cosmic rays that proclaim the continuous upbuilding of the universe, contrary to all the laws of thermodynamics. Jeans holds us spellbound with a poem about stars dying in a fierce radiance and bombarding us with cosmic rays in the process. Regener, as practical as the Irish foreman of a railway section gang when it comes to counting ions, looks at his equations as into a crystal and sees the beginning of things—sees primitive stars shedding cosmic rays and suffusing a relativistic universe from which they cannot escape because it is closed and finite. Stimulated by him, others imagine that, just as the bones of a dinosaur tell us something of the life that was on earth a few million years ago, so these fossil cosmic rays reveal the Almighty in the act of fashioning electrons and protons into nebulae, suns, planetary systems and man himself.

For all the instruments and methods invented to test the cosmic rays, the physicist is still the medicine-man from whom he is descended. Electroscopes and ionization chambers and other cosmic-ray measuring instruments seem strangely like wands and totem poles, and Einsteinian equations but incantations that make us believe we know more than we really do. That

[1] Address delivered before a joint meeting of the Washington Academy of Sciences and the Philosophical Society of Washington, December 15, 1932. Received December 15, 1932.

we are actually dealing with something like wish-fulfillments in the cosmic rays is evidenced by the results obtained. Here is Millikan convincing himself that the cosmic rays prove that the universe is self-perpetuating. And Compton, adopting precisely the same methods, reaches the conclusion that the rays are only electrons swerving to the poles because the earth is a great spinning magnet. What are the cosmic rays? There is no positive answer. We simply try to reconcile what the instruments indicate with our hopes and beliefs and imagine we understand the cosmos."

The same issue of the Times contains an editorial note entitled "It is Done with Mathematics" which reads:

"It is a relief to read that Professor Compton is back from studying cosmic rays in the Arctic region with the definite report that Professor Millikan is wrong. The cosmic ray, says Professor Compton, is not a wave, as Millikan thinks, but a particle.

It is a relief to find that when two men in the high realms of science hold opposite views one of them is right and the other is wrong. Hitherto the public has had to get used to the idea that when two great physicists differ radically about something in the universe the answer is that both men are right.

What is the electron, a wave or a particle? It spreads after going through a hole, like a wave. It hits other electrons like a particle. An electron is both a wave and a particle. That would be nonsense by the rules of common sense, but it makes sense in the new sciences. There is a formula for it.

Some people think that the universe is expanding. Some people think that the universe is contracting. They are both right, says science. Professor Eddington can think of its being an expanding universe and a contracting universe simultaneously. Or, rather, he can find a mathematical formula that will describe that startling situation.

In the same manner space is finite and space is infinite. There is a formula.

Obviously it is a delightful world in which you can have the coffee simultaneously hot and iced and out of the same cup, your egg simultaneously hard-boiled and scrambled, and the griddle cakes at the same time round and oblong.

But occasionally it is a relief to find black as the opposite of white and right as the counterpart of wrong."

Speaking to an audience of scientific men, we may pass with brief mention that portion of what I have read which deals with the disagreement of doctors. This is no new thing in science, and whenever it has occurred it has always been a passing phase characteristic of a stage at which our knowledge on a certain point was for the time too incomplete for unanimity of opinion. But beneath this good humored banter there is to be discerned a serious undercurrent to which we may well direct our attention.

The unsettled condition of modern physical theory has become a commonplace among physicists. It now appears that it has sufficiently penetrated the non-scientific world to produce a state of mingled wonder and bewilderment, suggestive of those earlier days when men

began to doubt the authority and infallibility of the Church. Moreover, it is noteworthy that this bewilderment of the editorial mind seems to be caused wholly by the doings and thinkings of physicists, if among these we may include astronomers, for what is astronomy but celestial physics? Chemists, engineers, geologists and biologists seem to call for no special mention. They are taken for granted as steady going fellows, cobblers with eyes not above their lasts, from whom society is in no danger. But physicists, it appears, are of different clay—iconoclasts, crack-brained theorists, ay, even writers of romance! And, if I guess rightly, this attitude of the editorial mind is not without a measure of instinctive sympathy on the part of many scientific men not of the physical persuasion.

Here is something for us physicists to think about. We are distinctly on the defensive on all sides. Why have we excited this suspicion? Why have we not been able to keep to the straight path with our fellows? If we are no longer regarded as safe and sane, is it our own fault, or that of the subject with which we have to deal?

It must be admitted that among the different conventional divisions of science physics occupies indeed a unique position. Ask the chemist the nature of the atoms and molecules with which he deals and of the forces which rule their reactions, and he will refer you to the physicist for an answer. Ask the biologist concerning the processes of the living tissues which he studies, and he will be apt to tell you that they are but complicated chemical reactions; and the psychologist, if his opinion be asked, will likely say that the subject matter of his study is the most complicated kind of physiology. The psychologist leans upon the biologist, the biologist upon the chemist, and the chemist in turn upon the physicist; but between the physicist and Nature there is no intermediary.

It is the task of the physicist to learn what he can about the fundamentals of Nature, matter and energy and their reactions, which as they rise in complexity form the subject for the study successively of the chemist, the physiologist, and the psychologist. Nor does the engineer, the geologist or the astronomer make use of any principles which may be called distinctively his own; all these merely apply the fundamental principles of physics or chemistry on a large scale. The physicist is, in the best sense of the word, a scientific fundamentalist. If therefore there comes about any change in basic scientific concepts it is the physicist in the front line who first feels the shock.

Now it happens that much of the new and strange in modern physical theory is bound up with two very fundamental concepts—matter

and the atom. In particular, it is noteworthy that a large majority of the published physical work for the last twenty years has been directly or indirectly connected with atomic theory. In this connection there comes to mind the exhortation of President John Adams to the chemists of his day:

> "Chymists! pursue your experiments with indefatigable ardour and perseverance. Give us the best possible Bread, Butter and Cheese, Wine, Beer and Cider, Houses, Ships and Steamboats, Gardens, Orchards, Fields, not to mention Clothiers or Cooks. If your investigations lead accidentally to any deep discovery, rejoice and cry "Eureka!" But never institute any experiment with a view or hope of discovering the smallest particles of Matters."

Is it the old story of Eden? Have we physicists eaten of the forbidden fruit of the tree of knowledge, and are we now suffering the consequences? However this may be, we will maintain, despite all accusations to the contrary, that our plight is not to be ascribed to original sin or to total depravity, but that the changes in fundamental concepts that are causing all the stir have been forced upon us as the logical result of approved methods of scientific study. And so compelling have been the reasons for these changes that there seems to be no more turning back possible for us than for our traditional first parents. We are thrust out of Paradise into contact with the bare world of Nature, and whether we like it or not we must somehow adjust ourselves to the new order of things. Concepts as old as human thinking are gone forever. Strange substitutes are replacing them, and until their novelty wears off it is inevitable that science should for the time appear as romance.

Would that it might ever remain so! But this is too much to expect. The thing that has been is that which shall be. Through familiarity we shall in time adjust ourselves to these new concepts as we have done to the telephone and more lately to the radio, once things of wonder, illumined by the halo of romance, but now mere commonplaces of our daily existence, matters of bargain and sale, at times even degenerating into nuisances and provocations to profanity.

The roots of the present revolution (or evolution) may be traced back for two centuries. The student of the history of science can discern during this period a certain trend of thought of which our present plight is but the logical outcome. This trend may be described as a steady drift away from materialism in our physical concepts.

The natural philosophers of the 18th century followed ancient tradition in explaining everything in terms of matter, which was re-

garded as a *sine qua non*, a basic concept without which physical thought would be impossible. Heat, in the 18th century, was a form of matter called caloric, which differed from ordinary matter in being unweighable, and which could be soaked up by ordinary matter like water in a sponge. Light was another imponderable in the form of very minute corpuscles. Electricity and magnetism were held to be manifestations respectively of the electric and magnetic fluids. Added to these was another imponderable called phlogiston, which was supposed to account for the phenomena of combustion. These five imponderables together with ordinary matter formed the stock in trade of 18th century physics.

The physical science of that period was a rather loose and disjointed affair, consisting mainly of uncorrelated facts about these six supposed entities. But within this chaos there was working the leaven of a principle stated by Newton in his "Principia" as the first of four "Rules of Reasoning in Philosophy": "We are to admit no more causes of natural things, than such as are both true and sufficient to explain their appearances. To this purpose the philosophers say, that Nature does nothing in vain, and more is in vain, when less will serve; for Nature is pleas'd with simplicity, and affects not the pomp of superfluous causes."

In this Newton was but repeating a rule of philosophy laid down three centuries earlier by one of the medieval schoolmen, William of Occam: "Essentials are not to be multiplied beyond necessity." This in its Latin form was a famous saying in the Middle Ages, and was known as "Occam's Razor." In modern parlance it would probably be called a pruning knife. In obedience to this principle the 19th century reduced these six essentials to three, and the 20th century went still further.

It is to be noticed that all the fundamental concepts of 18th century physics were regarded as material, whether they were weighable or not. The 19th century retained the concept of ordinary ponderable matter but did away with the imponderables, replacing them by two new concepts, distinctly immaterial in their nature—energy and ether. Light now became a vibration of the ether; heat was regarded, according to circumstances, either as an ethereal vibration like light (radiant heat), or as a mode of motion of the molecules of matter; and according to a text book of the period electrical phenomena were to be explained either as ether stress or ether flow, while magnetism was a matter of ether vortices. Thus at the end of the 19th century matter had been dethroned as sole monarch, but had been given a place as

a member of a triumvirate—matter, energy and ether—to which were entrusted all the affairs of the universe.

It remained only to take the final step, which was done in the twentieth century. Up to this time the application of Occam's razor to scientific philosophy had been universally approved as conducive to economy of thought and general solidification of theory. But when Einstein pointed out that the concept of matter was not an independent necessity, but could be merged with that of energy, the razor began to cut deep enough to hurt.

Einstein's argument was a strong one, for he showed clearly, and without any reference to relativity, that we must either regard matter as a form of energy or else disregard the experimental evidence for light pressure and also abandon Newton's laws of motion. As the latter alternative was more painful than the first, physical theory accepted the new cut of Occam's razor, eliminating the traditional concept of matter.

With the disappearance of matter as a basic entity the fundamentals of physics can best be described as disembodied ghosts masquerading under mathematical formulas.

"Hindsight is better than foresight." We could hardly expect this crash to have been foreseen, yet it is now clear that the concept of matter was doomed from the time that the trend set in against it. The progress of human thought is like that of some mighty glacier, slow but irresistible.

The atom has always been a subject of interest to physicists and many speculations as to its nature have been advanced. When matter was an unquestioned axiom the atom was explained on a material basis. Newton says in his "Opticks":

> "All things considered, it seems probable to me that God in the beginning formed matter in solid, massy, hard, impenetrable, movable particles, of such sizes, figures and with such other properties, and in such proportion in space as most conduced to the end for which he formed them, and that these primitive particles being solids, are incomparably harder than any porous bodies compounded of them; even so very hard as never to wear or break to pieces; no ordinary power being able to divide what God himself made one in the first creation."

With the growth of the concept of the ether there was a parallel tendency to explain atoms as ethereal phenomena. Kelvin suggested that an atom might be a vortex ring in the ether, something like a smoke ring in air. With the merging of matter into energy the difficulty of explaining the nature of the atom increased greatly, yet the interest in the subject has shown no sign of diminution.

Twentieth century experiment indicates that the atom is built up in some way of positive and negative charges of electricity. The present tendency is to regard the atom as electrical in its essence without committing ourselves to any definite hypothesis as to the nature of electricity. This electrical structure has taken several forms. Bohr's "solar system" model of the atom has "had its day and ceased to be." As far as our present ideas are capable of non-mathematical expression, the atom is to be considered as a collection of probabilities that an electric charge will be found here or there at points in a definite space pattern.

Nebulous and hazy as are our present ideas of the atom, it is evident that this condition is but a corollary to the parallel change that has taken place in our concept of matter, for if we have no clear idea of the whole how can we know more about its parts? We have seen that this change has come as the consequence of an attempt to apply the principle of simplicity and economy in thought as laid down by Occam and Newton. We physicists submit therefore that as far as matter and the atom are concerned the present state of physical theory is not our fault, but is the result of attempting to apply to our subject the most approved rule of philosophy.

The second editorial which I have quoted raises a new question. The bewilderment of the editorial mind is caused here by the bizarre results obtained from mathematical formulas. Here again we may disregard the disagreement of doctors and focus attention on the point of basic importance.

We physicists have used mathematics freely since the time of Newton and the results obtained have until lately always been regarded as regular and orthodox. It is only in the twentieth century that our mathematical conclusions have begun to appear fantastic.

The reason for this is not far to seek. There has been introduced into mathematical physics a body of doctrine which while familiar to mathematicians for upwards of a century had never been taken seriously by physicists prior to Einstein. I refer to the geometry of curved space and of space of more than three dimensions.

Perhaps nothing could be more transcendental and inconceivable than this hypergeometry, but mere inconceivability has never bothered mathematicians; nothing but inconsistency can do that. And it is a fact that once we admit the fundamental postulate of a fourth dimension it becomes possible to build up a hypergeometry as logical and consistent as that of Euclid.

The introduction of these novel concepts into physics has not taken

place without a struggle. Much of the opposition disappears, however, when one realizes that Einstein did not propose these hypotheses as physical facts, but merely as a sufficient, though not necessary, mathematical description of certain phenomena. He himself regards this child of his brain quite sanely. "No amount of experimentation," he is reported to have said, "can ever prove me right. A single experiment may at any time prove me wrong." Yet the theory of relativity has gradually gained a hearing and a growing acceptance because of performance, by its ability to do things a little better than was possible before. Though its conclusions often appear strange, some of them have been experimentally verified, and as a result we have added to our stock two new phenomena—the deflection of light rays passing close to the sun and the shift of the Fraunhofer lines in an intense gravitational field. With these practical results to support us, I think we may maintain that hypergeometry and the theory of relativity have justified their provisional acceptance as working tools, no matter how romantic their conclusions. Even the concept of an expanding universe may yet be experimentally verified. Things equally strange have happened.

We may now consider another possible item in the indictment against us, one of which we shall have to accuse ourselves, as it apparently had not yet reached the editorial mind. Physicists themselves have been much concerned over an attack by certain of their own number upon nothing less than the law of cause and effect. It is truly remarkable that such an attack should have come not from the anti-scientific but from the high priests of science themselves.

This latest skepticism concerns itself with the behavior of the electrons. The phenomena exhibited by these minute bodies have always been in some respects puzzling and incalculable, but scientific thought has been steadily optimistic, confidently awaiting the ultimate solution. The essence of the new view is that the behavior of an electron is incalculable, not because the problem is as yet too complicated for us, but because, to state it baldly, the actions of individual electrons are not governed by the ordinary law of cause and effect. The new philosophy recognizes that where an individual electron may be at this moment is a matter of observation, more or less imperfect; it admits that where the electron has been in the past is a matter of history; but it asserts that where it will be in the future is a matter not for definite prediction but only of statistical probability.

This doctrine appears to strike at the root of all law and order, and yet, curiously enough, its protagonists recognize the existence of a

kind of law on the large scale, but deny that it extends to individual units. The new philosophy is not such a complete reversion to primitive type as might be hastily concluded.

Perhaps the best illustration that we can give of this new thought is one based upon the behavior of units large enough to be familiar if not altogether comprehensible—human individuals.

The behavior of any individual under given conditions is, rigidly speaking, unpredictable. For your belief that I will react in a certain way to my environment you have nothing but a probability, perhaps a very high one, amounting to what you may consider practical certainty, but never more than a probability. No one can say with absolute certainty that I will not, let us say, steal money during the coming year. It may be in the highest degree unlikely that I will, so unlikely that you may consider it insulting to harbor any suspicion of me, yet experience shows that occasionally an ordinarily well-behaved man may do a most unexpected thing. While no one can say definitely just what you or I or he or she will do, yet with several millions of such individuals to serve as a basis for prediction it is possible to estimate just how many of them will depart from rectitude during the next year and how much money will be involved in the total sum. Such is the accuracy of this prediction that bonding companies risk their capital on it year after year, and make money. Individually, man is more or less of an enigma; in the mass he is a mathematical problem.

Something very like this is the latest turn of scientific thinking. It asserts that the future behavior of a single electron is incalculable. We can not tell whether it will turn to the left or to the right, whether its velocity will be accelerated or retarded. All that we can say is that there is a certain percentage probability of any particular behavior, and that such a prediction is always verified by the result when a sufficiently large number of electrons is taken into consideration. In the electronic realm there is no individual causal certainty. Instead there is something which in a conscious organism we would call caprice. Dirac even uses the term "the free will of Nature." Yet as we pass from the individual to the crowd certain laws begin to appear, but they are no longer causal laws; they are only laws of probability.

There is a certain measure of experimental support for this position. The evidence is rather involved, and is circumstantial and cumulative rather than direct and specific, but this is not a fatal objection. And there is an imposing array of authority which has accepted this evidence—Bohr, Heisenberg, Dirac, Jordan, Born, Eddington, Bridg-

man, and others. The situation has been well summed up by de Broglie in one of his essays from which I quote the following sentences.

"Causal laws replaced by laws of probability, physical individuals well localized and of well defined movement replaced by physical individualities which refuse to let themselves be simply represented and can never be more than half described: such are the surprising consequences of the new theories. In digging under these laws of probability, shall we succeed in re-finding causal laws as we have found recently behind the statistical laws of gases the causal laws of the movement of molecules? Certain arguments would lead to this belief, but it would be indeed imprudent to assert it.

What we have said suffices, we think, to show the importance of the change in the point of view which has recently taken place in physics. Whatever may be the final fate reserved for these new doctrines it is of infinite interest to philosophers that physicists have been led, even though but for the moment, to doubt the determinism of physical phenomena and to question the possibility of describing them in a complete fashion within the frame of space and time."

Perhaps it would be well now to pause, to catch our breath and see where we stand, if indeed we have anything left to stand on. Well may we echo the dismayed queries of Macbeth and Banquo after the disappearance of the three weird sisters:

"The earth hath bubbles, as the water has,
And these are of them. Whither are they vanish'd?"

"Into the air; and what seem'd corporal melted
As breath into the wind. Would they had stayed!"

"Were such things here as we do speak about
Or have we eaten of the insane root
That takes the reason prisoner?"

I think that we may feel safe as to the answer to the last question. The reassuring thing about all these new and strange theories is that they work. By means of them we are able to cut a little more closely to the line than was possible under the old regime. Practical physics was never more satisfactory; theoretical physics never less so.

This divergence between theory and practice is not to be understood as meaning that practice is being divorced from theory to its own advantage. On the contrary, there never was a time when practice was more closely dependent upon theory than today. New researches are almost invariably suggested by theory, and their results in a reasonable number of cases are confirmative of the theoretical prediction. Never was theory more fruitful. If we were totally on the wrong track, would Nature give us the abundant encouragement that she does? "By their fruits ye shall know them."

The difficulty with modern physical theory is not a lack of consistency; that mathematical requirement it possesses in abundance. It is the elusive and unreal nature of its fundamental concepts that gives us pause. But who are we that we should reproach Nature with being unreal? Perhaps the fault lies in our definition of reality, and of that Nature herself is the final and supreme judge. Guided by her answers to a century of experimental question, we have drifted steadily away from the material toward the immaterial in our fundamental concepts. If as a consequence science assumes an aspect of romance, perhaps this is because for the first time in the history of human thinking we have come close enough to reality to catch a glimpse of it. The picture is very different from that to which tradition has accustomed us, but so thought the contemporaries of Columbus and those of Galileo. And if the more closely we study Nature the more romantic she appears, perhaps we are but rediscovering something which the poets have always known and have not hesitated to utter.

> "And like the baseless fabric of this vision,
> The cloud-capp'd towers, the gorgeous palaces,
> The solemn temples, the great globe itself,
> Yea, all which it inherit, shall dissolve
> And, like this insubstantial pageant faded,
> Leave not a rack behind. We are such stuff
> As dreams are made on, and our little life
> Is rounded with a sleep."

Romance or science—which shall we call it? It matters little once we have been granted the vision to see that the two are not only consistent but inseparable.

MINERALOGY.—*Crystals of iron-rich pyroxene from a slag.*[1] N. L. BOWEN, Geophysical Laboratory, Carnegie Institution of Washington.

INTRODUCTION

In 1928 Dr. A. L. Day received from Mr. Oliver C. Ralston some specimens of a crystallized product formed in a slag during the cooling of a reverberatory furnace of the United Verde Copper Company, Clarkdale, Arizona. In his accompanying letter Mr. Ralston stated his opinion that the crystals would prove to be a high iron pyroxene, which opinion was entirely correct. At the time of their receipt the crystalline masses were turned over to the writer, but, aside from verifying their general character, no detailed study was made of them.

[1] Received October 7, 1932.

Since then a study of the system, CaO-FeO-SiO_2, has been completed[2] and pyroxenes of a like character found to form in mixtures belonging to that system. This fact led to a re-examination of the well crystallized slag material, the results of which seem worthy of record since they extend our knowledge of the crystallographic and optical properties of the pyroxenes to compositions richer in iron than any hitherto observed.

GENERAL CHARACTER OF MATERIAL

The masses consist of interlocking platy crystals of pyroxene from the interstices of which any excess slag that may have been present during their formation has drained away. Into the resulting vug-like spaces protrude euhedral crystals of pyroxene suitable for goniometric and optical measurements.

CRYSTALLOGRAPHY

The crystals are always tabular parallel to b (010), invariably show m (110) and o ($\bar{2}21$), and usually no other forms. On the 8 crystals measured two other forms were observed, s ($\bar{1}11$) occurring on two of them and z (021) on one of them. Reflection signals from the faces were fair to good. The crystals are:

Monoclinic $a:b:c = 1.0786:1:0.5828$

$\beta = 71°31'$

Observed and calculated interfacial angles are given in Table 1.

TABLE 1

OBSERVED AND CALCULATED INTERFACIAL ANGLES OF PYROXENE CRYSTALS

MONOCLINIC $a:b:c = 1.0786:1:0.5828$

$\beta = 71°\ 31'$

		Observed	Calculated
$b:m$	(010):(110)	*44° 20′	—
$b:s$	(010):($\bar{1}$11)	*60° 17′	—
$m:s$	($\bar{1}$10):($\bar{1}$11)	*60° 28′	—
$b:o$	(010):($\bar{2}$21)	47° 19′	47° 47′
$m:o$	($\bar{1}$10):($\bar{2}$21)	35° 53′	36° 17′
$m:o$	(110):($\bar{2}$21)	80° 54′	81° 3′
$b:z$	(010):(021)	42° 8′	42° 7′
$[b\ m]:[b\ o]$*		51°	51° 1′

* Intersonal angle measured on the stage of the microscope.

OPTICAL PROPERTIES

The plane of the optic axes is parallel to 010 and the extinction angle $(c \wedge \gamma) = +36°$. The refractive indices measured in immersion

[2] Bowen, Schairer, and Posnjak (soon to be published).

liquids under the microscope are $\gamma = 1.785$, $\alpha = 1.745 \pm .003$. The optic axial angle is small, $+2V = 20$–$25°$. The prismatic cleavage is perfect and the extinction on cleavage plates is 28°. Pleochroism is notable, γ = green, β = amber, α = smoky brown.

CHEMICAL COMPOSITION

The crystals of pyroxene contain abundant opaque inclusions. Some of these are fairly large and recognizable as dodecahedra of magnetite. Others appear as a mere dust which is, in part at least, a sulphide. The larger crystals can be separated, but when this is done the pyroxenic residue with its fine inclusions is still a rather unpromising material for analysis.

It is probable, therefore, that analysis of separated material would add little to the knowledge of the composition of the pyroxene already available in the form of a bulk analysis furnished by Mr. Ralston. The analysis is shown in Table 2.

TABLE 2

BULK ANALYSIS OF MATERIAL SELECTED BY MR. RALSTON

	Per cent
Cu	0.2
SiO_2	39.3
Al_2O_3	4.8
FeO*	43.4
Zn	3.5
CaO	2.7
MgO	3.3
S	1.1
	98.3

* All iron expressed as FeO.

We do not, of course, acquire an accurate knowledge of the composition of the pyroxene from this information but, knowing that there is only one silicate present whose silica ratio must be approximately that of a metasilicate, and that magnetite is the principal impurity, we may recalculate the analysis with the result given in Table 3.

TABLE 3

RECOMPUTED ANALYSIS OF SELECTED MATERIAL

	Per cent
$FeSiO_3$	69.3
$CaSiO_3$	6.7
$MgSiO_3$	8.2
Al_2O_3	4.8
Fe_3O_4	5.2
ZnS	3.4

Only a little Zn is thus left unaccounted for. It may enter into the pyroxene to some extent. The Al_2O_3 may be largely in the pyroxene, which may also contain some Fe_2O_3. Recognizing these elements of uncertainty we may yet say that the pyroxene does not depart greatly

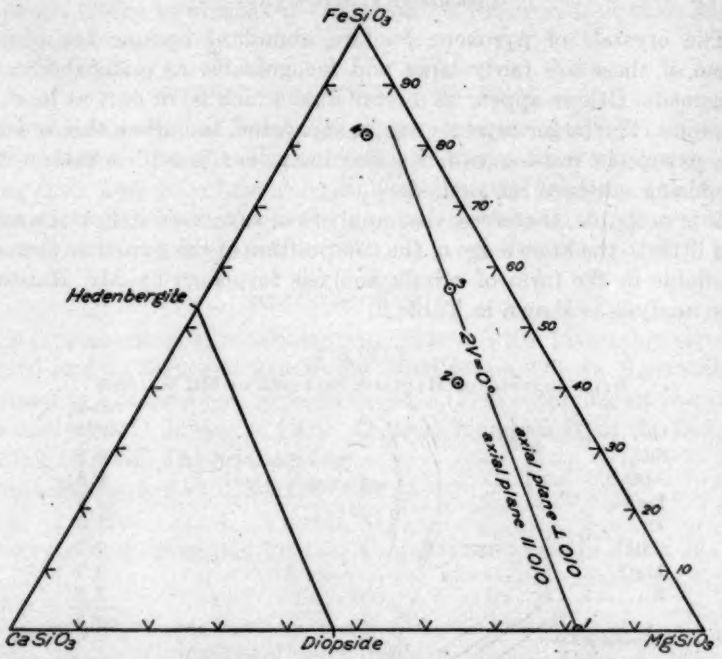

Figure 1.—Plot showing the composition of four pyroxenes of small optic axial angle.

1. Synthetic pyroxene $2V = 0°$. $\gamma = 1.670$. Bowen, Op. cit., p. 252.
2. Pyroxene from Föglö, Aland Islands $2V = 15–20°$. $\gamma = 1.711$. Wahl, Op. cit., p. 16.
3. Pyroxene from Mull $2V = 0°$. $\gamma = 1.744$. Hallimond, A. F., Min. Mag. vol. 17, p. 17, 1914.
4. Present slag pyroxene $2V = 20–25°$. $\gamma = 1.785$.

from a composition represented by the three metasilicate molecules at the head of the list. These, made up to 100, and rounded off to the nearest integer, give a composition $FeSiO_3$ 82 per cent, $CaSiO_3$ 8 per cent, $MgSiO_3$ 10 per cent. We may thus be sure that the pyroxene carries in the neighborhood of 80 per cent $FeSiO_3$.

The indicated content of $FeSiO_3$ far surpasses that yet found in any natural pyroxene and apparently in any slag pyroxene as well. The

measured high values of the refractive indices are in accord with this fact.

SYSTEMATIC RELATIONS

The pyroxenes of low optic axial angle and their chemical relation to the other pyroxenes have been of considerable interest ever since their discovery by Winchell[3] and the demonstration by Wahl of their widespread occurrence in certain types of rocks.[4] The present example extends our knowledge of them to a composition region hitherto unknown, a fact brought out in Fig. 1, which shows the relation to other pyroxenes of low optic axial angle. A straight line joining the composition of the synthetic pyroxene[5] (No. 1) with the point indicating the Mull pyroxene (No. 3) leaves the points for the other two pyroxenes (Nos. 2 and 4) only a short distance to the left, which is in accord with their very small optic axial angles and the position of the axial plane//010. Pyroxenes with compositions lying to the right of the line have the axial plane $\perp 010$. The position of the line of zero optic axial angle is necessarily only a first approximation since in plotting all the pyroxenes except No. 1 it has been necessary to neglect minor constituent molecules.

ACKNOWLEDGMENT

Thanks are due Mr. Ralston for sending us this interesting material.

CRYSTALLOGRAPHY.—*Vogtite, isomorphous with wollastonite.*[1]

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GENERAL CHARACTER OF VOGTITE

Under the name, vogtite, Hlawatsch in 1906 described some triclinic crystals obtained from a slag of unknown origin. Their composition was not determined but they appeared to correspond with crystals of the (Mg, Fe, Mn) SiO_3 series whose existence had been pointed out by Vogt, and to this series they were consequently referred.[2] Hlawatsch's crystals were well developed and he was able to

[3] Winchell, A. N., Amer. Geol., vol. 26, p. 199, 1900.
[4] Wahl, W., Tsch. Min. petr. Mitteil., vol. 26, pp. 1–131, 1907.
[5] Bowen, N. L., Amer. Jour. Sci., vol. 38, pp. 245–254, 1914.
[1] Received October 11, 1932.
[2] Hlawatsch, C., Z. Kryst., vol. 42, p. 590, 1906.

determine their angular constants. He referred them to a system of axial elements as follows:

$$a:b:c = 0.51826:1:1.11588$$

$$\alpha = 93°26'30'', \quad \beta = 103°59'12'', \quad \gamma = 83°50'8''$$

In 1919 Hallimond described similar material from the slag of an acid hearth steel furnace.[3] His crystals were analyzed (by J. H. Whiteley) with the result given in Table 1.

TABLE 1.—ANALYSIS OF HALLIMOND'S VOGTITE

	Slag crystals	mols.
SiO_2	47.4	0.790
Al_2O_3	0.15	
Fe_2O_3	2.7	.257
FeO	15.95	
MnO	12.95	.182
CaO	15.1	.270
MgO	5.26	.131
TiO_2	0.10	
	99.61	

The composition is not far from that of a metasilicate. The general formula may be written (Ca, Fe, Mn, Mg) SiO_3 in which Ca exceeds any one of the constituents in brackets with it but is very much in the minority as compared with the sum of these others.

Hallimond found his crystals to have essentially the same angles as those measured by Hlawatsch and gives a table showing their correspondence. Nevertheless, he chose a different orientation and referred them to the following system of axial elements:

$$a:b:c = 1.093:1:0.729$$

$$\alpha = 99°37', \quad \beta = 99°21', \quad \gamma = 83°53'$$

Hallimond's stereographic projection plot can be brought into coincidence with Hlawatsch's by simple revolution combined with a reversal; in other words, it refers to the opposite end of a crystal. Now if the Hlawatsch-Hallimond projection thus obtained is compared with the projection of wollastonite having its b axis in the pole of the projection, a remarkable agreement is found. All of the forms of vogtite show near coincidence with known or possible forms of wollastonite. The correspondence of faces in the ortho-zone of wollastonite with faces of the prism zone of vogtite is practically perfect. Of forms belonging to other zones e (Hlawatsch) and p (Hallimond) nearly coincide with (142) of wollastonite, d (Hlawatsch) with $(14\bar{2})$ of wol-

[3] Hallimond, A. F., Min. Mag., vol. 18, p. 368, 1919.

astonite and *l* (Hallimond) with ($\bar{3}42$) of wollastonite. The forms (142) and ($\bar{1}42$) of wollastonite have been observed only on crystals from Crestmore, California.[4] The form ($\bar{3}42$) has apparently not been observed on wollastonite.

The general correspondence of forms being thus qualitatively determined with the aid of a projection, the actual degree of correspondence is best shown by comparison of the numerical values of interfacial angles. This is done in Table 2. The angles given for vogtite are those

TABLE 2

RELATION OF FORMS OF VOGTITE TO THOSE OF WOLLASTONITE

Forms			Angles		
Vogtite (Hlawatsch)	Vogtite (Hallimond)	Wollastonite	Vogtite (Hlawatsch)	Vogtite (Hallimond)	Wollastonite
a (100)	*m* (110)[a]	*a* (100)[a]	*a*:*m* 50° 19′	*m*:*a* 50° 10′	*a*:*t* 50° 25′
m (110)[a]	*a* (100)	*t* (T01)[a]	*a*:*M* 44° 22′	*m*:*b* 44° 34′	*a*:*v* 44° 27′
t (120)[a]	*n* (3T0)	*α* (T02)[a]	*m*:*M* 94° 41′	*a*:*b* 94° 45′	*t*:*v* 94° 52′
b (010)[a]	*M* (1T0)[a]	*c* (001)[a]	*a*:*b* 95° 30′	*m*:*M* 95° 10′	*a*:*c* 95° 30′
M (1T0)[a]	*b* (010)	*v* (101)	*a*:*t* 69° 51′	*m*:*n* 69° 53′	*a*:*α* 69° 56′
d (011)	—	*ε* (T42)	*a*:*d* 80° 10′	—	*a*:*ε* 80° 29′
e (0T1)	*p*′ (01T)	*ω* (142)	*b*:*d* 64° 47′	—	*c*:*ε* 64° 15′
—	—	—	*a*:*e* 75° 26′	*m*:*p*′ 75° 30′	*a*:*ω* 75° 38′
—	—	—	*b*:*e* 61° 34′	—	*c*:*ω* 62° 11′
—	*l* (101)	— ($\bar{3}42$)	—	*m*:*l* 59° 39′	*a*:$\bar{3}42$ 58° 36′
—	—	—	—	*a*:*l* 50° 41′	*t*:$\bar{3}42$ 50° 40′

[a] Cleavage forms. *m* (Hlawatsch) doubtful.

found by Hlawatsch and by Hallimond. Wollastonite angles are, for the most part, taken directly from tables of interfacial angles in Dana's System. Those referring to the recently discovered wollastonite forms (142) and ($\bar{1}42$) are calculated from their ϕ and ρ values as given by Eakle. Those referring to the undiscovered wollastonite form ($\bar{3}42$) are calculated from the axial elements as given in Dana.

Little comment upon the table is necessary. It may be noted, however, that of the four cleavages of wollastonite, all in one zone, the two best were found in vogtite by Hallimond, and three of the cleavages found by Hlawatsch correspond with three of wollastonite, but the fourth Hlawatsch cleavage, although in the same zone, does not appear to correspond with the fourth wollastonite cleavage, which is the very best. It is possible that in his thin-tabular crystals the existence of a cleavage parallel to the tabular face may have been overlooked. However this may be, the remarkable agreement of vogtite with wollastonite cannot be gainsaid.

[4] Eakle, A. S., Bull. Dept. Geol. Univ. California, vol. 10, pp. 336–338, 1917.

ORIENTATION OF VOGTITE

All of this suggests that vogtite might be referred to a set of axial elements nearly identical with those conventionally assigned to wollastonite and be regarded as monoclinic. But vogtite is definitely triclinic as shown by the relation of the optical indicatrix to crystallographic directions. Moreover, wollastonite, hitherto regarded as monoclinic, has been shown by recent X-ray investigation to be of triclinic structure.

The study is by Warren and Biscoe, who say:

> "Altho wollastonite and pectolite are definitely triclinic they have a most unusual and pronounced pseudo-monoclinic symmetry. The angle γ is such that the 410 direction, which has always been taken as the direction of the 'a' axis, seems to make exactly 90° with the 'b' axis. What is even more striking is the fact that on the complete set of 'b' axis oscillation photographs all the spots on the even layer lines show perfect monoclinic symmetry, both as regards position and intensity of spots. This means that altho wollastonite and pectolite are triclinic, if the lattice were translated by an amount $b/2$ and superimposed upon itself the resulting configuration would have true monoclinic symmetry."[5]

The unit cell has dimensions which yield the axial elements:

$$a:b:c = 1.083:1:0.967$$
$$\alpha = 90°, \quad \beta = 95°16', \quad \gamma = 103°25'$$

In view of the near identity of the interfacial angles of vogtite and wollastonite the axial elements for vogtite will obviously be nearly the same, and it is somewhat superfluous to calculate them. Nevertheless, this has been done, with the following result:

$$a:b:c = 1.076:1:0.9643$$
$$\alpha = 90°43', \quad \beta = 95°10', \quad \gamma = 103°35'$$

In considering the position of the observed vogtite faces in this structure it is of interest to note the relation between the new and the old ratios for wollastonite. The commonly accepted constants referring it to monoclinic symmetry are

$$a:b:c = 1.0531:1:0.9676, \quad \beta = 84°30' \ (95°30')$$

In the new constants (already given) it will be seen that there is no change in the relative lengths of the b and c axes or in their rectangular relation to each other. The only change is in the a axis which is no longer perpendicular to b and is lengthened in accordance with its inclination of 13°25′ from that position. In virtue of this change the face with the symbol 140 referred to the old axes now becomes the pinacoid b 010. Likewise the observed vogtite faces, referred to the fundamental structure (new wollastonite axes), have their symbols

[5] Warren, B. E., and Biscoe, J., Z. Krist., vol. 80, p. 401, 1931.

notably simplified as compared with their symbols referred to the old wollastonite axes. The vogtite face which was found to correspond with 142 of wollastonite (old axes) now becomes 021, that corresponding with $14\bar{2}$ (old) of wollastonite becomes $02\bar{1}$ and that having the position of the unobserved $\bar{3}42$ (old) face of wollastonite becomes $\bar{2}21$.

FACE DEVELOPMENT IN WOLLASTONITE

The clinopinacoid 010 (old) has been observed only doubtfully on one occasion in wollastonite crystals. This fact, in itself, rather suggests a lack of agreement of the crystal lattice with the conventional axes, but the same reasoning would lead one to expect that the 140 (old) face should be very common since it is structurally the pinacoid 010 (new axes). In point of fact it was not until the measurement of crystals from Crestmore, California in 1917 that faces of that form were discovered. On these it is the most prominent "prism." The crystals are unusual in other respects. They exhibit no prisms bearing a simple relation to the conventional wollastonite axes, but do show the series 140, 340, 540, 740, and Eakle comments on the odd series of symbols. When these forms are referred to the new axes the symbols are transformed as follows, each monoclinic prism giving rise, of course, to two triclinic forms, $140 = 010$, $\bar{1}40 = \bar{1}20$, $340 = 120$, $\bar{3}40 = \bar{1}10$, $540 = 110$, $\bar{5}40 = \bar{3}20$, $740 = 320$, $\bar{7}40 = \bar{2}10$. The simplification of indices which results indicates a preference for the new axes on purely crystallographic grounds. In addition the Crestmore crystals are triclinic in aspect. On this point Eakle says: "Only one end of the crystals is terminated, sometimes the right and again the left end. The disposition of the faces indicates a lower grade of symmetry as there is no apparent axis of symmetry and the crystals could belong to the hemimorphic class of the monoclinic system, or to the triclinic system." But when all of this has been said it still is to be remembered that the Crestmore crystals are exceptional, and the remarkable fact remains that crystals of wollastonite, as described from other localities, have always furnished adequate justification for referring them to the monoclinic system and to the accepted system of axes. Prisms having simple indices referred to these axes are very common in wollastonite. In this respect the related pectolite is more straightforward. It shows the prisms 140, 340, 540, and none other. They have, as noted above, much simpler indices referred to the new axes.

POSITION OF THE OPTICAL INDICATRIX

Another remarkable feature of wollastonite is the fact that the *b* axis, which has always appeared to be an axis of symmetry, should

also appear to coincide with an axis of the optical ellipsoid. Ordinarily this is a very satisfactory test of monoclinic symmetry, for, even in a case where the angular departure of faces from such symmetry is too small to detect, there is little reason to expect that the departure of the optical ellipsoid from parallelism would also be very small. In order to check previous observations on wollastonite some Crestmore crystals[6] were examined for parallelism of the extinction direction, with the *b* axis, i.e., the zone of cleavages. The results appear to indicate a slight extinction angle (1.5–2°) in the section which shows normal emergence of the acute bisectrix. The inclination of the extinction direction is not readily observed in this section in the ordinary manner in parallel light. The optic axial angle of wollastonite is so small that the position of extinction is not sharply defined. The observation is perhaps best made in the interference figure in convergent light. When the crystal is in the parallel position, with respect to the planes of the nicols, the black cross is appreciably opened and a slight revolution is necessary to produce a definite cross. In a section showing normal emergence of an optic axis a similar effect is obtained. The one end of the black bar is appreciably curved when the crystal is in the parallel position and a slight revolution is required to obtain a straight bar. In other positions in the "ortho" zone the extinction is sensibly parallel.

These observations do not furnish absolutely convincing evidence of inclined extinction in wollastonite, for anomalous optical behavior resulting from various causes, such as strain, could produce this result. Nevertheless, they furnish adequate justification for urging that mineralogists carefully observe these relations in wollastonite wherever encountered.

In vogtite Hallimond found an extinction angle of 5° in a section normal to the acute bisectrix and parallel extinction in a section normal to the obtuse bisectrix.[7] Hlawatsch observed an extinction $\beta \wedge b$ of 9°–14°.[8]

SIGNIFICANCE OF ISOMORPHISM OF VOGTITE AND WOLLASTONITE

Whether the crystallographic similarity of wollastonite and vogtite indicates a solid solution relation is a question that may now be

[6] From the U. S. National Museum through the courtesy of Dr. W. F. Foshag who also called my attention to Eakle's description of them and their triclinic aspect.

[7] Hallimond, A. F., Op. cit., p. 369.

[8] Hlawatsch, C., Op. cit., p. 590.

raised. In view of the discovery that wollastonite is triclinic there is no objection on the ground of a difference of crystal system. However, an isomorphous relation does not necessarily indicate a solid solution relation. We may recall only the case of $CaCO_3$ and $CaMg(CO_3)_2$ which are isomorphous, i.e. similar in forms and angles, but there is no series of carbonates of intermediate composition. The relation between wollastonite and vogtite might be of a similar character.

In this connection it is desirable to note the recent studies of manganese-bearing triclinic pyroxenes by Sundius. As a result of his painstaking study of bustamites Sundius concludes that they are simply manganese-bearing wollastonites, i.e., wollastonite solid solutions.[9] Nothing is known of the crystallography of bustamite except the cleavage angle, and Sundius's conclusion is based on his demonstration that the observed variation in optical properties (including orientation of indicatrix) of the known series of bustamites, when extrapolated to zero content of $MnSiO_3$, gives, sensibly, the properties of wollastonite. Unfortunately the amount of extrapolation is some three times the extension of the known series of bustamites. The existence of this wide gap in the supposed series rather weakens the conclusion, indeed bustamites cluster so closely around a 1:1 ratio of $CaSiO_3$ to $MnSiO_3$ that one is led to wonder whether the relation between wollastonite and bustamite is not similar to that between calcite and dolomite. Sundius attempts to explain the existence of the hiatus with the aid of a subsidiary assumption regarding the character of the equilibrium diagram which he regards as rendering unlikely the formation of intermediate representatives of the series although the full series really exists. The considerations that he raises in that connection will not, however, bear critical examination, and the existence of the wide gap between wollastonite and bustamite remains unexplained if bustamite really is a wollastonite. These objections to certain aspects of Sundius's reasoning are pointed out merely because it is considered desirable that any weakness his conclusions may have should be fully brought out. It is not with the plan in mind of offering an opposed conclusion. On the contrary it is believed that Sundius has almost certainly reached the correct conclusion when he states that bustamite is merely a manganese-bearing wollastonite and that all gradations of composition can exist. The reasons for this belief come from purely collateral evidence. In a study of the system, CaO-FeO-SiO_2, now completed[10] it has been found that a continuous series

[9] Sundius, N., Am. Mineral., vol. 16, pp. 421–423, 1931.

[10] By Bowen, Schairer, and Posnjak, soon to be published.

of iron-bearing wollastonites is obtained; indeed, it was to prepare the ground for a description of this series that the present paper discussing related materials has been written. From this continuous series of wollastonites bearing iron it is but a short step to the vogtites bearing manganese as well as iron, and from these again but another step to bustamites with manganese predominating and iron unimportant. They are probably all just wollastonites.

The full evidence regarding the series of iron-bearing wollastonites will be given in the paper detailing the equilibrium studies on the system, CaO-FeO-SiO_2, and will include the evidence of optical properties and of X-ray diffraction spectra. The results obtained for vogtite and bustamite by these methods will then be given for comparison.

SUMMARY

Vogtite is a silicate formed in slags and shown by Hallimond to have the general formula (Ca, Fe, Mn, Mg) SiO_3. In the Hallimond example Ca exceeded any one of the other basic elements but was very much less than their sum. Both Hlawatsch and Hallimond made crystallographic studies and found the crystals to be triclinic. Their measurements of interfacial angles agree, but Hallimond chose a different orientation from that previously chosen by Hlawatsch with correspondence only in the position of the *c* axis (prism zone).

If vogtite is oriented in such a way that the prism zone corresponds with the ortho-zone of wollastonite a remarkable agreement is found in forms and angles of the two species. The extent of this agreement is brought out in Table 2. Wollastonite itself, as a result of X-ray studies, is now known to be triclinic and its new constants have been determined. Vogtite is therefore to be referred to a similar system of axes. The values are:

Wollastonite $a:b:c = 1.083:1:0.967$, $\alpha = 90°$,
$\beta = 95°16'$, $\gamma = 103°25'$

Vogtite $a:b:c = 1.076:1:0.964$, $\alpha = 90°43'$,
$\beta = 95°10'$, $\gamma = 103°35'$

The isomorphism of wollastonite and vogtite is of interest in connection with the problem of bustamite. Although isomorphism alone does not necessitate the existence of solid solution there are the strongest reasons for believing that vogtite is simply a wollastonite solid solution and the likelihood that bustamite is also a wollastonite, as Sundius maintains, becomes very great.

ZOOLOGY.—*A new genus for the nematode* Filaria cistudinis *Leidy, 1856, of the family Filariidae.*[1] JOSEPH E. ALICATA, Bureau of Animal Industry. (Communicated by BENJAMIN SCHWARTZ.)

The material on which the discussion of the nematodes described in this paper is based, consists of a male and two females collected by the writer from the heart cavities of a turtle, *Terrapene carolina*. The host animal was captured in June, 1932, in the vicinity of Washington, D. C. The nematodes in question belong to the family Filariidae Baird, 1853, emend. Claus, 1885, and to the subfamily Aproctinae Yorke and Maplestone, 1926, and possess characters which differ from those of any of the existing genera of the subfamily. They are accordingly considered as constituting a new genus for which the name *Cardianema* is proposed.

The filarids discussed in this paper are probably identical with the species reported by Leidy (1856) as *Filaria cistudinis* from the heart of the same species of turtle, *Terrapene carolina*, presumably collected in Pennsylvania. Leidy's description of the form reported by him is as follows: "*Filaria cistudinis*. Body capillary, spirally involute, attenuated at the extremities. Head and tail obtusely rounded. Mouth unarmed. Anus terminal. Length 1½ inches, breadth ⅛ of a line. One specimen was obtained by Mr. Schafhirt from the heart of *Cistudo carolina*." Although Leidy's description is meager, the occurrence in the same host and the same location, both in the eastern United States, and the general appearance of the worms, which shows a similarity between the form described by Leidy and those found by the writer, indicate that the writer's material is *Filaria cistudinis*. The only detail in Leidy's description which does not apply to the writer's specimens is the position of the anus. Leidy, as noted above, reports the anus as terminal; the present writer finds that it is located some distance from the tip of the tail. Because the anus of this parasite, and of filarids generally, is inconspicuous and rather easily overlooked, it is probable that Leidy actually overlooked the anus, and that he mistook a cuticular structure or indentation for the anus. The specific name proposed by Leidy for the turtle heart-filarid is retained in this paper, the name of the species becoming *Cardianema cistudinis* (Leidy, 1856).

The systematic position of the parasite is as follows:

Subfamily APROCTINAE Yorke and Maplestone, 1926

Subfamily diagnosis.—Filariidae: Mouth simple, usually without lips;

[1] Received October 5, 1932.

cuticle smooth or with longitudinal or transverse striations; trident-like structures on each side of anterior end of esophagus absent; vulva anterior, or slightly posterior, to terminal portion of esophagus; spicules relatively short, equal or subequal, and similar; anus usually not functional, sometimes absent.

The position of the genus *Cardianema* in the subfamily Aproctinae and the relationship of this genus to the other known genera of this subfamily are shown in the following key:

Key to genera of subfamily Aproctinae

The genera included in this subfamily, with their distinguishing characters, have been taken for the most part from Yorke and Maplestone's (1926) key.

1. Anterior portion of spicules tubular and chitinous, posterior portion twisted and membranous; parasites of circulatory system of turtles ..... *Cardianema*
   Spicules not divided into tubular and membranous portions 2
2. Males with caudal alae; parasites of muscles and tendons of legs of birds ..... *Pelecitus*
   Males without caudal alae 3
3. Amphidelphic 4
   Opistodelphic 5
4. Mouth surrounded by a cuticular collar; parasites of subcutaneous tissue of birds ..... *Squamofilaria*
   Mouth simple, without a cuticular collar; parasites of body cavity of birds ..... *Chandlerella*
5. Esophagus very narrow and transparent; parasites of subcutaneous tissue of birds ..... *Eufilaria*
   Esophagus of ordinary type 6
6. Posterior extremity of both sexes digitiform and prolonged considerably beyond anus; parasites of subcutaneous connective tissue of geckos ..... *Thamugadia*
   Posterior extremity of both sexes terminating very close to tip of tail 7
7. Esophagus divided into a short anterior narrow portion, and a long posterior wider portion; parasites of mesentery of lizards ..... *Saurositus*
   Esophagus not divided into two distinct portions 8
8. Gubernaculum absent; parasites of orbital and nasal cavities of birds ..... *Aprocta*
   Gubernaculum present; parasites of birds; location unknown ..... *Pseudaprocta*

Cardianema, new genus

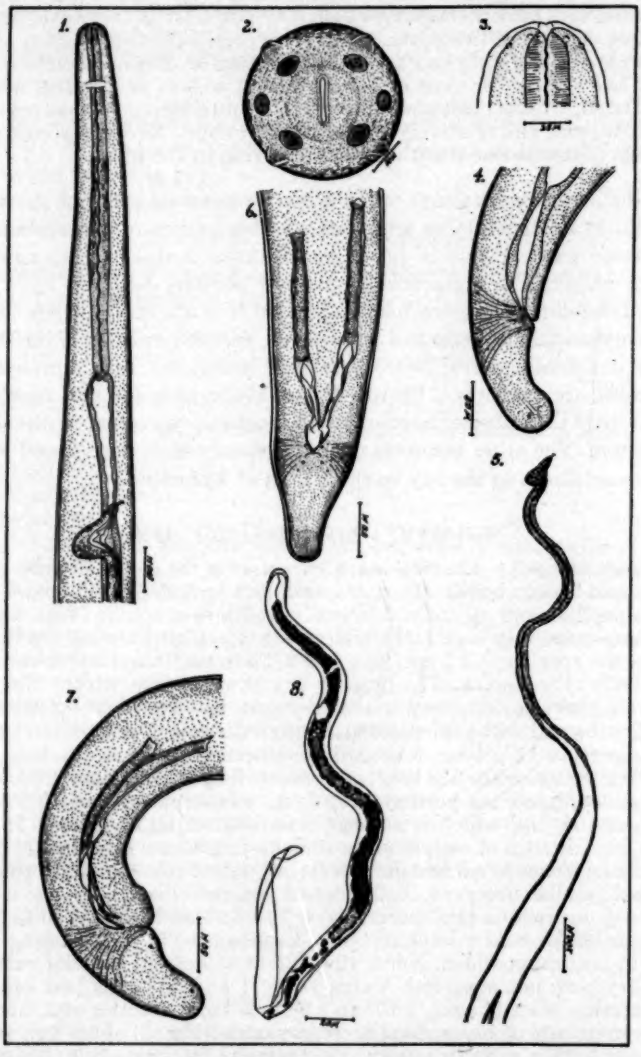
Generic diagnosis.—Aproctinae: Long and slender worms, whitish in color, loosely coiled, and attenuated toward extremities. Cuticle with fine longitudinal striations. Mouth simple, elongated dorso-ventrally, surrounded by 4 pairs of submedian papillae and a pair of lateral papillae or amphids. Esophagus simple, relatively long and slender. *Male* with slender, subequal spicules, consisting of an anterior tubular portion and a posterior membranous portion, the latter terminating in a spade-like tip. Caudal papillae small and indistinct, consisting apparently of one pair of pre-anal and two

pairs of post-anal papillae. Tail relatively long, bluntly rounded terminally, and curved ventrally. *Female* vulva slightly posterior to terminal portion of esophagus. Vagina in two parts, an anterior portion or true vagina, which is short, wide and sac-like, and a posterior portion or uterine vagina, which is tubular and slender for most of its length, but widens as it unites with two parallel uteri. Uterus opistodelphic; worms ovoviviparous, uterus containing eggs and larvae. Tail relatively long, bluntly rounded terminally, and curved ventrally. Microfilariae sheathed and occurring in the blood.

The distinguishing features of the genus *Cardianema* are: The spicules are not uniform in structure as are those of other genera of the subfamily; in *Cardianema* each spicule is made up of three distinct parts, namely, a straight, tubular, well chitinized proximal portion, followed by a transparent, twisted membranous median portion, and a terminal spade-like posterior portion. Of the genera of Aproctinae, six are parasites of birds, while the two remaining genera, *Saurositus* and *Thamugadia*, each represented by one species, are parasites of lizards. It should also be noted that *Cardianema* is apparently the only member of the Aproctinae occurring in the circulatory system. The other members of the subfamily have been found in other locations as shown in the key to the genera of Aproctinae.

CARDIANEMA CISTUDINIS (Leidy, 1856)

Specific diagnosis.—Cardianema: Characters of the genus. Worms slender, filiform and loosely coiled. Head rounded, and provided with 4 pairs of submedian papillae and one pair of lateral papillae or amphids (Figs. 2 and 3). Esophagus relatively long and slender (Fig. 1). *Male* (description based on writer's one specimen) 2.5 cm. long and 235μ in maximum width near equator of body. Esophagus 873μ long by 34μ in maximum width. Nerve ring 159μ from anterior extremity. Excretory pore not observed. Spicules (Figs. 6 and 7) subequal; right spicule 201μ long, consisting of a chitinized proximal tubular portion 117μ long, a median membranous portion 53μ long, and a spade-like posterior tip 31μ long; left spicule longer than right spicule, 221μ long, proximal tubular portion 129μ long, membranous portion 72μ long, and spade-like tip, which is smaller than that of right spicule, 19μ long. Cloaca 86μ from tip of tail; muscles surrounding cloaca prominent; papillae surrounding cloaca small and indistinct; one pair of pre-anal and two pairs of post-anal papillae observed. Tail directed ventrad (Fig. 7). *Female* (description based on writer's two specimens) 2.7 to 3.2 cm. long by 266 to 288μ in maximum width near middle of body. Esophagus 775 to 988μ long and 42 to 53μ in maximum width. Nerve ring 125 to 152μ from anterior extremity. Excretory pore not observed. Vulva (Figs. 1 and 5) opens just below terminal portion of esophagus, 1.107 to 1.28 mm. from anterior end. According to measurements of one specimen, true vagina (Fig. 5) short and sac-like, 150μ long by 91μ wide; uterine vagina tubular, 2.2 mm. long, 45μ wide at junction with sac-like portion of true vagina, and widening to 144μ at the point where it joins the two uteri. Uteri contain eggs and larvae; eggs in uteri oval, about 26μ long and 11 to 15μ wide. Two larvae *in utero* were 225μ long and 9μ in maximum width, which corresponds approximately to size of larvae found in blood. Anus small, 99μ from tip of tail; muscles surrounding anus prominent. Tail curved ventrad; tip bluntly rounded (Fig. 4).



Cardianema cistudinis.—1. Female, anterior portion (ventro-lateral view); 2. Female, anterior end (*en face* view); 3. Female, anterior end (ventral view); 4. Female, posterior portion (lateral view); 5. Female, showing vulva, true-vagina, uterine vagina and beginning of uteri; 6. Male, posterior portion (ventral view); 7. Male, posterior portion (lateral view); 8. Microfilaria from the blood.

Microfilariae from heart blood were stained with Wright's stain. Smears made by rubbing pieces of liver on slides revealed numerous ensheathed microfilariae in blood of liver also. Two small, oval, pearly cysts, 740 to 780μ long by 289 to 305μ wide, found on the surface of the liver, were opened with dissecting needles, and found to be tough connective tissue cysts, 15μ thick, each containing a microfilaria; this finding of microfilaria in cysts appears to be unusual, but probably represents a defense reaction of a customary sort, commonly invoked against other parasites and perhaps invoked against microfilariae oftener than is supposed.

Microfilariae (Fig. 8) inclosed within a sheath which is considerably longer than the worm it contains. Larvae, excluding sheath, 190 to 280μ long by 9 to 12μ in maximum width. Anterior extremity bluntly rounded; body more or less uniform in width up to a point slightly posterior to the granular mass, tapering gradually from this point and terminating in a somewhat short digitiform tail. The anterior extremity of the larva did not take stain. Following a short area of a stained portion is the nerve ring which appears as an obliquely unstained band extending across width of body, 42 to 65μ from anterior extremity. So-called "V spot," or excretory pore, opens to outside 10 to 20μ posterior to nerve ring; excretory cell just posterior to excretory pore. Approximately at equator of body, 90 to 135μ from anterior end, is beginning of so-called granular mass, a dark purple-stained area, extending postequatorially 35 to 60μ. Of what appear to be the genital cells the first one is immediately posterior to granular mass, the second about 18μ posterior to first cell, and the third and fourth cells arranged one behind the

TABLE 1. DIMENSIONS (IN MICRONS) AND PROPORTIONS OF SEVEN CARDIANEMA CISTUDINIS LARVAE FROM THE BLOOD OF TERRAPENE CAROLINA

	1	2	3	4	5	6	7
(1) Length (without sheath)	190	200	210	220	240	268	280
(2) Maximum width	9	9	11	11	11	12	12
(3) Distance from anterior extremity to nerve ring	42	45	45	48	57	62	65
(4) Distance from nerve ring to excretory pore	10	10	15	15	15	20	20
(5) Length of tail	14	20	20	23	23	23	28
(6) Percentage of body length anterior to nerve ring	22.1	20.5	21.4	21.8	23.7	23.1	23.2
(7) Percentage of body length anterior to excretory pore	27.3	27.5	28.5	28.6	30	30.5	30.3
(8) Difference between (7) and (6)	5.2	7	7.1	6.8	6.3	7.4	7.1
(9) Percentage of body length anterior to tail	92.6	90	90.4	89.5	90.4	91.4	90
(10) Distance from anterior extremity to granular mass	90	100	108	115	120	125	135
(11) Length of granular mass	40	35	38	45	42	45	60

other shortly posterior to second cell. The so-called tail-spot, another unstained area, is 14 to 28μ from tip of tail. Tail contains few stained elements.

Host.—Definitive: Turtle (*Terrapene carolina*); intermediate: unknown.

Location.—Adults in cavities of heart; ensheathed larvae in blood of primary host.

Distribution.—United States (Pennsylvania ?) and vicinity of Washington, D. C.

Specimens.—U. S. N. M. Helm. Coll. No. 32604.

Table 1 shows the principal measurements of seven larvae, and certain size relationships in percentages.

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ZOOLOGY.—*Egg-laying habits and larval stages of a milliped,* Arctobolus marginatus *(Say) Cook, native at Washington.*[1] H. F. Loomis, Bureau of Plant Industry. (Communicated by O. F. Cook.)

Early in the summer of 1916, Mr. H. S. Barber, of the U. S. National Museum, was collecting insects in the woods on the Virginia shore of the Potomac River at Plummer's Island, a short distance above the city of Washington, when beneath the loose bark of a fallen tree he discovered a female milliped of the large, cylindrical, native species, *Arctobolus marginatus* (Say) Cook, in the act of laying her eggs. As soon as he realized what the milliped was doing he replaced the bark without disturbing her, and ceased further investigation of the log. Several days later, on June 2, I visited the same spot with Mr. Barber and we began a careful search of the rotting tree trunk for millipeds or their eggs, both of which were found to be numerous,

[1] The notes forming the basis for this paper were made a number of years ago and are far from complete, but deal with interesting phases in the life history of an animal belonging to a little-known group of arthropods. As an opportunity for continuing the study may not present itself again it seems desirable to put these observations on record. Received October 5, 1932.

as also were recently hatched young. The bark loosely covered the partially rotted interior, into which the millipeds had worked their way, and by the movement of their bodies had formed small chambers in the soft material. In some of these chambers the females had begun to lay eggs, whereas in others egg-laying had not started. Of all the millipeds found in this log, none were males. Likewise, in a search of the leaf-mould in the vicinity only females of this species were found and some of these also were laying.

On this visit no attempt was made at detailed observations, but gravid female millipeds, eggs, and recently hatched young were placed in tin boxes with a quantity of the moist, rotten wood, for further study.

Some of the females had already laid part of their eggs in the log but others apparently had not begun to lay, so that a count of the eggs subsequently laid in the individual boxes in which the females were kept gave an indication of the number of eggs that might be produced by a female at one "nesting." The greatest number of eggs laid by any one of these females was 261, while seven others produced the following numbers—216, 204, 203, 189, 186, 153, 74. These eggs were deposited between June 2 and 11, after which no more eggs were laid.

From observations on the imprisoned millipeds and those in natural surroundings it was apparent that this species had a definite egg-laying season, but there may have been at least one other such period in the fall, for on August 4, 1916, Mr. Barber noted numbers of these millipeds in the same locality mating on the tree trunks at night, and it is supposed that the eggs then fertilized were laid a few weeks later, instead of being held through the winter for laying the following spring, ten months after fertilization. Also it is probable that these were of the same generation of females which had been seen laying eggs in early June.

In this species of milliped it was found that the mother enclosed each egg in an individual pellet composed of what was, at first, thought to be the material constituting the excrement pellets, but closer examination showed the egg pellets to be of a lighter colored, coarser substance, containing tiny fragments of rotten wood, leaves, (and fungi?). Several times, by carefully opening the tin containers, the millipeds were caught in the act of forming these egg cases and were watched undisturbed practically throughout the entire process of encasing the egg in the pellet.

The first step in the manufacture of one of these egg cases was the

regurgitation of a small mass of material by the mother, who curved her head so that the mass was delivered to the legs a short distance behind the head, the eighth to eleventh pairs of legs receiving the moist lump. These legs held the mass while the milliped curved her head around still further and began flattening and spreading the material by repeatedly forcing the smooth, convex front of her head against it, until soon there was formed a thin saucer or shallow bowl, smoothed on the convex side by the milliped's head, but with a rough exterior. In the center of this saucer the egg was placed immediately following its ejection from one of the paired oviducts which in millipeds, contrary to what might be expected from the position of the oviducts in most other arthropods, are located just behind the second segment, at the front of the body. The actual placing of the egg in the saucer was not observed but probably was accomplished by the mother's bending her body over the saucer and laying the egg directly in it, although it might have been possible to have the egg passed back from the oviduct and placed in the saucer by the legs between the oviduct and those holding the receptacle. As soon as the egg was deposited, the edges of the saucer were brought up and kneaded together by the feet, while the junction was rapidly worked over by the front edge of the head or labrum, and this action of head and feet was continued until an almost perfect sphere, with a slightly roughened surface but without folds or cracks, was formed. The completed pellet was dropped by the mother and she soon began a repetition of the process for the next egg.

The completed egg pellets measured 3 to 3.5 mm. in diameter, with walls slightly less than a millimeter thick, leaving the egg lying loose in a chamber 1.5 to 1.8 mm. in diameter. The egg pellets were somewhat intermixed with excrement pellets but were distinguished from them by being nearly round, by having a rougher surface caused by the varied material from which they were made, and by the fact that these pellets, when exposed to the air, dried to a light brown color much faster than the excrement pellets, which had a finer texture that held moisture better, were oval in shape, and whose surfaces were smoother. The walls of the egg pellets formed the first food eaten by the young millipeds; each pellet containing enough food to last the milliped through several of its earliest stages of growth.

Occasionally the egg-laying and pellet-making processes were not conducted with routine exactness as was shown in one pellet where two eggs had been deposited by the mother, one being left slightly

exposed and forming part of the surface of the pellet. In another pellet the egg was visible through a carefully rounded, smooth-edged hole in the side, which possibly was left because of insufficient material to complete the pellet. At another time the mother had fashioned a pellet which outwardly was indistinguishable from the other egg pellets, but on breaking this pellet it appeared that no egg had been deposited in the perfectly moulded chamber.

The eggs were creamy white in color and broadly oval in shape, being about 1.3 mm. in their longest diameter and 1.1 mm. in the shortest diameter. All descriptions that have been noted in milliped literature refer to the eggs of millipeds as being round instead of oval. Moreover, all the eggs that have been found by the writer in collecting these animals have also been round, with this one exception. The formation of an edible pellet about each egg does not appear to have been reported for any other milliped, and from a quotation on a succeeding page, from a paper by J. W. Bailey, it appears that this custom is not followed throughout even the genus *Arctobolus*. Millipeds belonging to some of the other orders make definite nests in which they lay their eggs, but the eggs are not placed in individually manufactured cells, nor is any provision made by the mother for supplying the newly hatched young with food.

The egg pellets made by each of the females imprisoned in the tin boxes on June 2 were removed several days later and placed in separate boxes where they were examined from time to time. On July 9, first stage "larval" millipeds were found by breaking the egg pellets and a few second and third stage young were also seen there. Although some of these young necessarily had been present in previous examinations of the boxes they had been overlooked because it was expected that the young millipeds would emerge from the pellets as soon as they were born, whereas it was first discovered on July 9 that the young millipeds normally remained in the pellets for a considerable time after hatching and there underwent several changes. Subsequently it was determined that they remained in the pellets throughout the first two stages of their life and finally ate their way out during the third stage—usually in the latter part of this stage—when nearing the time for the third moult. Eggs continued to hatch until July 13, on which date no unhatched eggs could be found in the tins and there were only about a quarter as many millipeds in the first stage of growth as in either the second or third stages, indicating that the majority of the eggs had hatched considerably before this

date. From the rather limited observations it appeared that the period of incubation lasted from three to five weeks, but no very conclusive data were obtained.

The incubation period of the eggs in the tin boxes manifestly was about a week less than for similar eggs left in the log from which came the females used for observation. Warmer temperatures doubt-

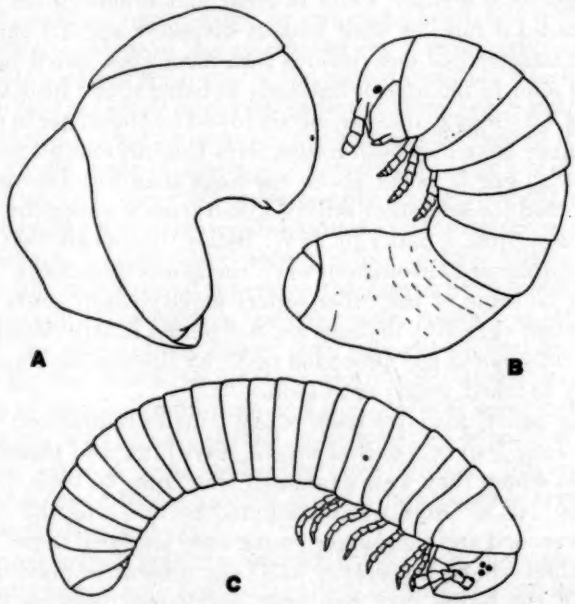

Fig. 1.—Three stages of *Arctobolus marginatus*. A. First stage, with portions of the egg-shell still adhering, head and segments not differentiated, the eye spot faintly indicated, the appendages still unformed. B. Second stage, with 6 definite segments and 3 pairs of legs. C. Third stage, with 21 segments and 7 pairs of legs.

lessly accounted for the more rapid incubation of the eggs in the tin boxes. Hence, it was assumed that from four to six weeks usually were required for the incubation of the eggs of this milliped under natural conditions.

When an egg hatched the shell usually split almost all the way around the middle, forming subequal halves narrowly joined together, the halves opening up, like a clam, exposing the young milliped in its first stage of life. During this stage the brownish eggshell

was not cast off but remained on the back of the milliped until the first moult had taken place.

Contrary to statements found in zoological text books and scientific papers on immature millipeds, the first stage "larva" of *A. marginatus* did not have a distinct head followed by definite segments, and there were no legs or antennae visible. Instead, the animal appeared as a short, white grub, somewhat angular in the region of the mouthparts; covered by a very delicate semi-transparent membrane or skin of uniform texture, through which a single eyespot on each side of the head and a suggestion of segments could be seen (Fig. 1). Although this skin was retained by the animal until the first moult it did not appear to be attached to the animal and was removed from several of the young to allow direct examination of them. They were found to have a distinct head and six well-formed segments, followed by a slightly swollen, abdomen-like portion, composed of indistinct rings, terminating in a soft but rather evident, truncate last segment containing well-defined anal valves and preanal scale. A brownish eyespot was found on each side of the head although this did not develop to a normal ocellus until the moult. The very short antennae appeared to be indistinctly 4-jointed, but the mouthparts were soft, unchitinized, and amorphous, and it was doubtful if the animals ate anything during this stage. There were no legs, but on segments 1, 2, and 3, small, elevated prominences or tubercles were noted in the locations where the legs would develop at the first moult.

The period of time passed by the animals in this first stage and in succeeding stages was not determined as the writer's unexpected departure from Washington occurred before the study of this feature of development was well under way.

Following the first moult, in the second stage of their existence, the young millipeds were short, white in color, and each had a well-developed ocellus on either side of the head, in addition to which, at times, there were two brownish eyespots which would develop into ocelli at the second moult. The mouthparts were of definite shape and moderately chitinized, and the mandibulary stipes slightly hollowed to receive the antennae. The antennae were quite short and capable of being somewhat telescoped, and there were five joints, with the four apical sense cones readily seen. Behind the head were six well-developed and definitely chitinized body segments, each of the first three with a pair of 6-jointed legs, as in mature individuals; the legs terminating in a strong, appendiculate claw, the needle-like appendage of which was below and nearly half the length of the main part

of the claw. All the joints of the legs had one or two strong setae on the ventral face. Segment 6 of the body had no indication of repugnatorial pores. The posterior half of the body resembled a soft, indistinctly ringed abdomen, with the last segment, valves, and preanal scale as described for the first stage young.

In the third stage, which succeeded the second moult, the still uncolored young millipeds could no longer be mistaken for insect larvae as they had a strongly chitinized body, composed of twenty-one distinct segments, infrequently twenty-two segments, and each of the first five of these bore a single pair of legs, while segment 6 bore two pairs of legs. The ensuing segments constituted two-thirds of the length of the body and were footless and showed no indication of where the legs to be added at the next moult would come. The second segment was not produced forward below segment 1, as it would be in after life. The last segment, anal valves, and preanal scale were shaped as in mature animals. A repugnatorial pore was visible on each side of segment 6 but there was no indication of pores on the segments thereafter. The antennae had six distinct joints, and the three fully developed ocelli formed a triangle on each side of the head; the mandibulary stipes were deeply excavated for the reception of the antennae. It was when nearing the end of this stage that the millipeds ate their way out of the food pellets made by the mother when the eggs were laid.

The fourth stage millipeds had twenty-six or twenty-seven segments and, in either case, the last six segments were legless. Thus females had thirty-five or thirty-seven pairs of legs, as the first five segments each had one pair of legs while the succeeding segments each had two pairs as far as the legs extended. Although many fourth stage millipeds were examined no males were detected, but it is possible that they would have had thirty-three or thirty-five pairs of legs, for the leg arrangement would be the same as for females except that segment 7 probably would be without legs because in the final stages of growth the males have the legs of this segment greatly modified and hidden within the body, the structures generally being referred to as "gonopods" and only functioning during mating. The animals were light brown, finely mottled with uncolored spots above and below, except on the posterior legless segments which were uncolored. In this stage the forward production of the second segment below the corner of segment 1, so evident in mature individuals, was first observed. The repugnatorial pores were present from segment 6 to the last pedigerous segment inclusive. The antennae had six obvious

joints, and on each [redacted] of the head six ocelli usually formed an equilateral triangle, but [redacted]me specimens the number of ocelli in each eye was reduced to three or four.

The structural notes on the growth stages following the fourth moult were never completed, but segment counts of a small number of young millipeds indicated that there were at least three more stages before maturity was reached.

Millipeds in the fifth stage had thirty-two segments, and their eyes were composed of eight to ten ocelli.

Of eight sixth-stage young, two had thirty-six segments, four had thirty-seven segments, and two had thirty-eight segments; the ocelli numbered thirteen to fifteen, with one individual in which there were but eight ocelli on one side of the head and ten ocelli on the other.

In what was assumed to be the seventh stage, three millipeds had forty-one segments, one had forty-three segments, and three had forty-four segments, and the ocelli ranged from eighteen to twenty-one.

Mature specimens of this species have been reported with forty-seven to fifty-seven segments and thirty to forty ocelli composing each eye. Those examined by the writer usually had between fifty and fifty-five segments and thirty-six to forty-three ocelli. In view of these figures it is probable that an eighth and possibly a ninth stage occurs in the life history of this species before maturity is reached.

In regard to the moulting of these millipeds, particularly in the early stages, it was observed that just prior to the moult the posterior legless portion of the body became noticeably elongated, with the segments considerably exposed, as much as the pedigerous segments, whereas after the moult these legless segments were strongly telescoped and hidden within each other, and the body was a lighter color than immediately preceding the moult. Following the moult the body remained quite soft for a day or two but gradually hardened and, in the later growth stages, assumed an increasingly darker color.

In early May several years prior to the observations reported in this paper, H. S. Barber, interested in the life history of *A. marginatus* in relation to the food habits of the giant glow-worm, *Phengodes laticollis* Lec. endeavored to find where and how the eggs of this milliped were laid by placing about twenty full grown specimens of both sexes in a deep jar set in the ground and filled with leaf-litter for food. His subsequent observations are quoted below.

"By the end of July young had appeared in the jar although it had previously been examined without finding eggs. At this time, however, it was

discovered that in most cases the excrement pellets were not solid but consisted merely of a thin shell surrounding a comparatively large cavity in which the small brown-skinned egg was lying loose. These pellets showed no external difference from the solid normal pellets cast by large individuals of the species, but when exposed to the air for a few minutes the color changed slightly on account of the more rapid drying out of the thin shell. About a pint of both kinds of pellets was placed in tin boxes where they could be frequently examined. By the middle of August most of the young myriapods had devoured their enclosing pellets and were feeding on the solid ones. They measured 8 mm. in length and had seven pairs of legs, but some were moulting into a slightly longer, many-legged (35 pairs) form. Before the middle of September they had reduced all of the frass pellets in the tin into a mass of very fine frass and were crawling on its surface seeking other food. They congregated on bits of rotten wood that were introduced and began feeding, but the condition of this rotten wood was apparently unsuitable, and a few days later all were found dead on the surface, many having had all their legs eaten off by those who survived the longest."[2]

Several points of divergence may be noted which partly arose from the fact that the egg-laying habits had not been observed. Also it is appropriate to note the observations of another writer on what is probably a different species of the genus *Arctobolus* although referred to *marginatus*.

J. W. Bailey[3] listed *Spirobolus marginatus* as the only species known to occur in the state, and on page 13 made the following statements in discussing the habits of the Diplopoda.

"*Spirobolus*, one of the most common and the largest of the Diplopoda found in New York State, deposits its eggs in damp, wet places, usually in some decaying stump or fallen log. The pearly white eggs, about the size of a small buckshot, are deposited in June, July and August; usually 15 to 20 in a batch. The eggs are never covered with dirt, as in *Julus* or other species. The period of incubation is said to be ten to 18 days. The young emerge from the eggs as partially developed larvalike creatures having only three pairs of appendages as do other members of the class Diplopoda."

That the true *Arctobolus* (*Spirobolus*) *marginatus* is not native to New York State, but is a more southern species, was pointed out by O. F. Cook in describing *A. onondaga*, from Onondaga County, New York, as the type of the genus.[4] The strikingly different egg-laying habits of the New York species is an additional reason to consider it distinct from *marginatus*, but its identity with *onondaga* cannot be

[2] Barber, H. S., Fragmentary notes on the life history of the Myriapod, *Spirobolus marginatus:* Proc. Ent. Soc. Wash., vol. 17, no. 3, 1915.

[3] Bailey, J. W., The Chilopoda of New York State with notes on the Diplopoda: N. Y. State Mus. Bull. 276, 1928.

[4] Cook, O. F., Myriapoda of northwestern North America: Harriman Alaska Exped., pp. 64–65, 1904.

certified without comparing specimens with the description or the type specimen of *onondaga*.

East of the Mississippi, principally in the South Eastern and South Central states, there are about eight recognized species of millipeds belonging to the genus *Arctobolus;* whereas west of the Mississippi closely allied genera contain about the same number of species. In view of the differences in egg-laying habits between the New York species and the one about Washington, variation of the same habits of the other species undoubtedly occur, and investigation of these species should furnish interesting facts, which conceivably might also be of value in determining the systematic relationships of the species.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

GEOLOGICAL SOCIETY

493D MEETING

The 493d meeting was held at the Cosmos Club October 26, 1932, Vice-President HESS presiding.

Informal Communications.—W. C. MANSFIELD in company with Mr. HERMAN GUNTER, State Geologist of Florida, upon a recent trip up the Suwanee River, discovered, about a mile and a half upstream from White Springs, an unconformity between the tampa limestone and the sandstone of the overlying Hawthorne formation.

H. D. MISER described three sink-hole deposits in Ordovician limestone, all near Rolla, Missouri. One sink-hole contained flint clay with diaspore; another contained deposits of limonite, hematite, and magnetite, all probably derived from pyrite; and the third sink-hole contained coal of Pennsylvanian age. The coal deposit has the form of a vertical column 90 feet in diameter and 180 feet long, and is entirely surrounded by fire clay. All three deposits have been worked commercially.

Program: N. H. DARTON: *New geologic map of Texas.*

C. WYTHE COOKE: *Pleistocene changes of sea level.*—The alternating accumulation and melting of the continental ice caps during the Pleistocene epoch caused repeated fluctuations of sea level amounting to several hundreds of feet in amplitude. The sea was low during the glacial stages and high during the interglacial stages. During each resting stage that was of sufficient duration the sea engraved a high-water mark or a low-water mark on the land and thus recorded the position of its shore at various stages. But the height of sea level is also affected by any crustal movements that change the capacity of the oceanic basins. Therefore, the present altitude of the high-water marks or abandoned shore lines can not be attributed ex-

clusively to glacial control, for they record the net lowering of sea level due to all causes. The high-water marks now stand about 12, 25, 42, 70, 100, 170, 215, and 270 feet above the present sea level except where they have been deformed by Pleistocene or Recent movements of the land.

Eustatic shore lines make very useful datum planes by which to correlate the various phases of Pleistocene history because they encircle all continents and islands. It may be possible to correlate the glacial and interglacial stages in different parts of the world by the reference of each stage to its corresponding shore line. The discovery by Leverett of pebbles washed out of the Illinoian moraine in the deposits of the 100-foot stage (Wicomico formation) shows that the 100-foot shore line can not be older than Sangamon interglacial time, which immediately followed the Illinoian glaciation. From this as a starting point one can arrive at a hypothetical correlation of the shore lines with the interglacial stages by assigning each successive shore line above 100 feet to an interglacial stage successively older than the Sangamon and each successive shore line lower than 100 feet to a successively younger interglacial stage. This disposes of every definitely recognized Pleistocene shore except the 12-foot, which is attributed to lowering of sea level from some cause other than glacial control. The 42-foot and the 25-foot shore lines are tentatively correlated with the first and second interglacial substages of the Wisconsin, respectively. As glacial geologists think that the polar ice caps during these temporary retreats of the Wisconsin ice were larger than the existing ice caps, glacial control alone may not account for any of the lowering that leaves them high and dry today.

A series of seven paleogeographic maps of South Carolina shows that the shore line at each stage of the sea differed markedly from those that came before and after. The shore of the 70-foot stage, which is tentatively correlated with the Peorian, gives evidence of long-continued stability of the sea at that level. Much of the erosion that dissected the region of the Sea Islands appears to have taken place during the low-water stage of the first Wisconsin glaciation. (*Author's abstract.*)

Discussed by Mr. W. C. MANSFIELD.

HUGH D. MISER: *Oklahoma structural salient of the Ouachita Mountains.*—The Oklahoma structural salient of the Ouachita Mountains comprises their western portion, lying mostly in Oklahoma but partly in Arkansas. Its northern frontal margin, a great arc 180 miles in length, trends in a northeasterly and then easterly direction along the northern edge of the mountains in Oklahoma and then passes in a southeasterly direction across the mountains in western Arkansas. In the salient, as well as elsewhere in the mountains, a vast succession of rocks ranging in age from Cambrian to Pennsylvanian and having a thickness of 25,000 feet has been deformed by late Paleozoic folding and faulting. In Oklahoma the front of the salient is marked by thrust faults which bring together two different facies of rocks, the Ouachita Mountain facies and the Arbuckle Mountain facies. Toward

the south the rocks of the Ouachita facies pass underneath the Cretaceous rocks of the Gulf Coastal Plain and occupy a wide belt extending in a southwesterly direction into Texas, past the east side of the Central Mineral region, and thence in a westerly direction to and beyond the Marathon region. Likewise, the Oklahoma salient appears to pass into Texas, but how far it extends into that State is not determinable from the available data provided by wells that have reached the pre-Cretaceous floor.

The deformation of the rocks in the salient was produced by compressive movements from the southeast and the frontal portion of the salient appears to have been thrust northwestward a distance of 20 miles or more over the rocks of the Arbuckle Mountain facies in Oklahoma and also in northern Texas. The structural trends of the Arbuckle facies near the Red River are toward the southeast, whereas the trends in the adjacent portion of the Ouachita geosyncline are toward the southwest. It thus appears that the northwestward thrusting of the Oklahoma salient took place after the major periods of deformation of the rocks of the Arbuckle Mountain facies.

The structural features that are revealed in the Oklahoma salient are characterized by long parallel thrust faults, which bound northwestwardly-thrust nappes. The longest fault, the Choctaw, has a length of 125 miles. Toward the southwest the faults pass underneath the Cretaceous rocks of the Coastal Plain and their extent in this direction is thus not known, but toward the east the faults die out near the eastern margin of the salient and terminate near the Arkansas-Oklahoma line.

The deformation of the rocks of the portion of the Ouachita Mountains east of the salient resulted from movements from the south. Here the characteristic type of structural deformation is close folding much of which is isoclinal; there is a notable absence of thrust faulting; and all the available evidence based on structural and stratigraphic field studies by me and other geologists shows clearly that the northern margin of the Ouachita Mountain facies of rocks is not limited by thrust faults in Arkansas as it is in Oklahoma.

The presence of a portion of a salient in central Arkansas seems to be indicated by the arcuate arrangement of the structural trends between Little Rock and Hot Springs. It may be appropriately designated the Little Rock salient. The greater portion of this salient is concealed by the Cretaceous and younger deposits of the Gulf Coastal Plain.

The arcuate trends of the Ouachita geosyncline in Oklahoma and Texas, whereby it changes from west to southwest in Oklahoma and then bends toward the west in central Texas, seem to suggest that the geosyncline probably has a curved course east of the east end of the Ouachita Mountains in Arkansas. To me, it appears possible that the geosyncline passes eastward in Arkansas and thence southeastward across the Mississippi River to join the Appalachian geosyncline in Alabama. The form of the supposed Little Rock salient would be similar to the form of the Oklahoma salient. Also, the reentrant salient of the Ouachita geosyncline in central Texas would be

similar to such a salient in the geosynclinal area between Arkansas and the Appalachians in Alabama.

Deposits of erratic boulders, mostly of pre-Carboniferous rocks, are found along and near the northern margin of the Ouachita Mountains. With the exception of deposits near Boles, Scott County, Arkansas, they are all confined to the Oklahoma salient. None of the deposits is found along the thrust faults that bound the nappes and they can thus not be regarded as having a tectonic origin that is related to such faults. Instead, they are all confined to a single formation, the Caney shale of Carboniferous age. My present conclusions, which are based on field evidence that has been obtained by me over a period of many years, are that the boulders are not remnants of thrust sheets, nor are they fault breccia, but they appear to have been brought into the Ouachita geosyncline during Caney time through some unusual means of transportation, perhaps by ice rafting. The boulders thus appear to form a part of the stratigraphic sequence in the Ouachita Mountains, and do not appear to be related in origin to any structural features of the mountains. (*Author's abstract.*)

Discussed by Mr. E. O. ULRICH.

494TH MEETING

The 494th meeting was held at the Cosmos Club November 9, 1932, President F. E. MATTHES presiding.

Informal communication.—H. G. FERGUSON outlined the tentative plans for the meetings of the 16th International Geological Congress to be held in the U. S. Chamber of Commerce Building, the last week in July.

Program: C. S. ROSS.—*Genesis of titanium deposits of Nelson County, Virginia.*

Discussed by Messrs. HESS, SCHALLER, and GILLULY.

WATSON H. MONROE: *Topography and physiography from aerial photographs.*—When two photographs taken of the same area from different points and correctly oriented with respect to each other are viewed through a stereoscope, the image of the area common to both is seen in relief. Therefore, with single-lens vertical aerial photographs with a mutual overlap of 60 per cent between adjacent pictures it is possible to construct several kinds of hypsographic maps without using a machine of the aerocartograph type. A controlled form-line map intermediate in accuracy between a simple form-line map and an accurate contour map can easily be constructed at low cost of time and money. Such a map is accurate enough for most uses. Horizontal control by transit traverse and vertical control by a large number of spot elevations determined by carefully checked barometer or plane table traverse are necessary for this type of map. Form lines controlled by the spot elevations are drawn on one of two overlapping photographs viewed through a stereoscope. All features such as roads, streams, houses, railroads and the form lines are then traced on cloth with differences in scale and correct

orientation of the photographs provided for by an intersection net previously prepared. The tracing is then reduced to the desired scale by photography.

Many physiographic forms such as old land surfaces, drainage changes, submerged coastal features and land forms, that can not be seen from the ground or on topographic maps, can be understood when studied on aerial photographs.

In the northwestern part of the Jackson quadrangle, Mississippi, there has been recent dissection of an old plain, beheading of streams, and development of right-angled drainage. These features can not readily be detected from the ground and are not shown on the topographic map made in 1901.

Photographs of the Pearl River, Mississippi, swamp show a large number of lakes and sloughs scattered through the woods. The Pearl River at various stages in its history used these for its channel but has since abandoned them. Maps of the river, made in 1821 and 1901, when superimposed on a new map of the river traced from photographs, show a number of changes in the channel, but the old channel is represented by some of the lakes and sloughs. Much of the year the swamp is impenetrable and a map could not be made by ground methods alone except at a prohibitive cost.

For a comprehensive picture of the area such as that afforded by a drainage map of a large area, a mosaic is to be preferred. For detailed examination of the topography, the overlap of two adjacent photographs should be studied with a stereoscope. (*Author's abstract.*)

Discussed by Messrs. K. E. LOHMAN, TRASK, and MATTHES.

T. A. JAGGAR: *Elevation changes, horizontal shift, and tilt at Kilauea Volcano.*—The cycle of rise of lava and the tumescence at Kilauea in the years 1913–1924, was followed by fall of lava and subsidence, and ended by engulfment and a steam-blast eruption in 1924, and occupied a little more than 11 years. Mauna Loa made lava gushings at the summit crater in 1914, part way down the slope in 1916, and into the sea in 1919, all within this Kilauea cycle. Sympathetic sudden sinkings of Kilauea lava occurred at the end of each Mauna Loa episode. Examination of the record of 134 years next preceding 1924, beginning with the last steam-blast eruption at Kilauea in 1790, reveals twelve evident cycles involving the Mauna Loa-Kilauea system. It also reveals a supercycle with minima of lava pressure at low levels at the beginning and end of the nineteenth century, and maxima in the middle of the period—1790–1924—and the maxima at high levels on Mauna Loa. (See Volcano Letter No. 325.)

R. M. Wilson has completed critical triangulation and levelling of Kilauea crater and vicinity during the epoch 1921–1922 and compared it with the survey of 1926–1927. It shows a lowering of the mountain top of 13 feet and horizontal inward shift of the country rock 2 to 4 feet. This was the period of the great engulfment collapse. The curve of level change bends steeply close to the inner pit, but the effects extend outward at least twenty miles.

Level changes between 1912 and 1921 show a bulging up of the mountain top differentially 1.58 feet in 4 miles at the summit region. General elevation during this high-pressure lava period was indicated but not certain, owing to critical uncertainties of rod-length and sea-level datum. Precision increased with each new survey.

Fortunately the seismographs at the northeast edge of Kilauea crater registered all tilts. These were of the order of 60 seconds outward in 1918–1920 during the rising lava period, and 70 seconds inward during the 1921–1924 collapse. Much of the latter actually accompanied the steam-blast engulfment, so that the tilt data may be profitably studied, as timing the events, indicated by comparison of the triangulation and levelling changes. Mr. Wilson's report which is to be published by the U. S. Geological Survey considers rigorously, order of precision, probable error, and absolute datum.

The Hawaiian Volcano Observatory has built three tilt cellars equally distributed about the Kilauea lava pit, and these are equipped with clinoscopes reading direction and amount of tilt daily. E. G. Wingate is in charge of this work, and also of the levelling and triangulation. (*Author's abstract.*)

495TH MEETING

The 495th meeting was held at the Cosmos Club, November 23, 1932, President F. E. MATTHES presiding.

Informal communication.—Miss TAISIA STADNICHENKO described the structure and microscopic characters of a sample of the coal from the sinkhole deposit in Missouri which Mr. MISER described at the 493d meeting of the Society. The coal is bituminous and of high rank, not laminated but more massive and canneloid in appearance. Thin sections show that it contains an abundance of spores, a subordinate amount of woody material but nevertheless a considerable quantity of fusain or mineral charcoal. It is probably not a coking coal.

W. H. BRADLEY: *Factors that determine the curvature of mud-cracked layers.* —Three factors play a predominant role in determining the curvature of polygonal, mud-cracked layers or plates; (1) the vertical grain size gradient, that is, the decrease upward (or downward) in the size of grains; (2) the presence of salt crystals; and (3) the rate of drying. Theoretical principles controlling the shrinkage of drying muds and the experimental work of students of moist soils and muds, indicate that the finer the grain size, and the greater the proportion of clayey, flake-like particles, the greater the shrinkage capacity and cohesiveness of the mud. These principles, checked by experiments and field observations, lead to the generalization that the polygonal plates of a drying mud tend to become concave toward the finest grained material and that the amount of curvature varies directly as the grain size gradient. Mud-cracked layers may become convex upward if the grain size decreases downward. This may result either from inversion of the normal decrease upward in the grain size or from the growth of salt crystals

in the upper layers whose grain size is thereby coarsened with respect to the lower layers. The ultimate effect of the rate of drying on most muds is negligible but in very fine, even grained muds the rate of drying becomes the dominant factor controlling the curvature of the dried layers. In these muds exceedingly slow drying produces either flat, or slightly concave plates, but rapid drying causes the plates to become markedly convex upward. Consequently, if salt crystals or their molds are absent, the convexity of mud-cracked layers can be used as a criterion of salinity only when the convexity owing either to rapid drying of very fine, even grained mud or to inversion of the normal grain size gradient can be definitely excluded. (*Author's abstract.*)

Discussed by Messrs. RUBEY, PARKER, and THOMPSON.

B. L. CLARK: *The Mt. Diablo thrust.*

Discussed by Messrs. STOSE, WOODRING, MATTHES, GOLDMAN, HENDRICKS, HEWETT, and FERGUSON.

496TH MEETING

The 496th meeting of the Society was held at the Cosmos Club December 14, 1932, President F. E. MATTHES presiding. Vice President F. L. HESS took the chair during the presentation of the presidential address: *The evolution of the glacial cirque.*

40TH ANNUAL MEETING

The 40th annual meeting was held at the Cosmos Club after the adjournment of the 496th regular meeting, President F. E. MATTHES presiding. The annual report of the Secretaries was read. The Treasurer presented his annual report showing an excess of assets over liabilities of $1,677.50 on December 9, 1932. The auditing committee reported that the books of the Treasurer were correct.

The results of balloting for officers for the ensuing year were as follows: *President:* C. N. FENNER; *Vice-Presidents:* H. G. FERGUSON and R. C. WELLS; *Treasurer:* C. WYTHE COOKE; *Secretaries:* W. H. BRADLEY and T. B. NOLAN; *Members-at-large of the Council:* E. KIRK, C. E. RESSER, E. T. MCKNIGHT, M. N. BRAMLETTE, and D. G. THOMPSON; *Nominee as Vice-President of the Washington Academy of Sciences representing the Geological Society:* F. E. MATTHES.

J. F. SCHAIRER and W. H. BRADLEY, *Secretaries.*

SCIENTIFIC NOTES AND NEWS

Prepared by Science Service

NOTES

Washington at the Atlantic City Meetings.—Washington institutions and scientists took part in the midwinter meetings of the American Association for the Advancement of Science and affiliated societies, in Atlantic City

from December 26 to 31. Three federal departments, Agriculture, Treasury, and Commerce, displayed exhibits; and other Washington exhibitors included the Smithsonian Institution, the Carnegie Institution, Mr. CHARLES BITTINGER, and Mr. HUGH CLARK and Miss LEILA G. FORBES.

The Department of Agriculture exhibit consisted of a demonstration of damage caused by the Mexican bean beetle and methods for its control, and a demonstration of the surgical use of blowfly larvae in treating infected wounds, and of methods of rearing them under aseptic conditions.

Representing the Treasury Department, the U. S. Public Health Service showed graphically how the ancient hard-times scourge of the South, pellagra, has been conquered by a proper appreciation of its origin in dietary deficiencies and the development of low-priced dietary auxiliaries to supply those deficiencies.

For the Department of Commerce, the Bureau of Standards displayed a flask of "heavy water," containing an excess of hydrogen isotope 2, which is denser than ordinary water by as much as 180 parts in a million. The Bureau also showed a method of demonstrating the effect of traces of base metal impurities upon the appearance of mercury, by producing large bubbles, 1 or 2 cm. in diameter, through a mixture of mercury and dilute nitric acid. Flakes of rock salt showing plastic deformation, and recently determined spectra of rare elements completed the exhibit.

The Coast and Geodetic Survey displayed a new type of accelerometer, which operates and records vibration for predetermined ranges of vibration.

The Bureau of Fisheries showed samples of fish flour, fish meal, and fish oil, canned oysters and canned salmon, with charts demonstrating their nutritional value, especially newly developed data on their vitamin contents, and the usefulness of oysters in combating nutritional anemia.

The Smithsonian Institution exhibit was by the division of Radiation and Organisms. It consisted of apparatus developed for the measurement of photosynthesis as a function of wave length and intensity of light and carbon dioxide concentration; special light sources and filters; and illustrations of the photochemical and lethal reactions of algae under various wavelengths.

The U. S. National Zoological Park had an exhibit of the Surinam toad, which is rarely seen in zoological gardens.

The Carnegie Institution of Washington displayed results of the research work of several of its departments during the past year, especially the new measurement of the velocity of light conducted at Mt. Wilson, and photographs of the Mercado from Chichen Itzá.

Mr. BITTINGER, a well-known Washington artist, showed paintings of several types of spectra, some of them made with pigments of a new type specially made for accurate color representation.

Mr. CLARK and Miss FORBES displayed an unrecorded manuscript map of the prehistoric Indian earthworks near the confluence of the Muskingum

and Ohio rivers, drawn by Henry Livingston, Jr., in 1788. It appears to have been the prototype of several later maps of the same region.

The resignation of Dr. CHARLES F. ROOS, permanent secretary of the American Association for the Advancement of Science, has been announced. Dr. Roos will be succeeded by Dr. HENRY B. WARD of the University of Illinois, who will take office in the late spring.

Damage by Fire at Catholic University.—A fire of undetermined origin broke out in the upper part of MacMahon Hall at the Catholic University of America early in the morning of January 6 and wrought severe damage to the botanical laboratory. A preliminary estimate of the total losses is set at approximately $25,000. The greatest harm was the destruction of a collection of plants from the region of San Antonio, Texas, valued at about $1,000, and the burning of a set of taxonomic charts made by the late Dr. Theodor Holm, which are of course irreplaceable. Severe damage was also done by smoke to the botanical library.

Minimum temperatures on Mt. McKinley.—The U. S. Weather Bureau has just tested the historic minimum thermometer that the late Archdeacon HUDSON STUCK cached at a place 15,000 feet above sea level on the slope of Mount McKinley, Alaska, in the summer of 1913, and that was recovered last May by another climbing party. The instrument was brought to Washington for testing by Mr. HARRY J. LIEK, superintendent of Mount McKinley National Park, one of the men who found it. The tests showed it to be an excellent instrument.

When the thermometer was found last spring, the index was not only considerably below the lowest graduation of the scale (93°F. below zero) but was projecting into the bulb in such a position that it could go no farther. Apparently this position denotes the occurrence of a minimum temperature, some time during the 19 years the thermometer lay on the mountain, of at least 100° below zero, and perhaps several degrees lower. The evidence furnished by the thermometer for this remarkably low temperature is by no means conclusive, as the index may have been jarred out of its correct position by wind, and there are other possible conditions that may have affected the correct action of the instrument during its long sojourn on the mountain. But on the other hand, it is thought that a temperature of 100° below zero or lower is not impossible at an altitude of 15,000 feet on this subarctic mountain.

Radio Talks.—W. L. MCATEE, of the Biological Survey, urged the "Preservation of Wild Life along the Potomac" in a radio talk broadcast in the program of the Rod and Stream Department of the Washington *Evening Star* on December 1. "No more useful or interesting task," he concluded, "beckons local members of the Izaak Walton League, and of the Audubon Society, and like organizations, than constantly to urge that all

of the Potomac River that is to be bordered by park projects be made a wild life refuge, to see further that the essential natural features of this great reservation are preserved, and finally, to be on guard at all times against their despoliation."

On December 23, Dr W. B. BELL, of the Biological Survey, spoke over the radio on reindeer in Alaska. Under the auspices of Science Service, the talk was broadcast from Station WJSV and 56 associated stations of the Columbia Broadcasting System.

NEWS BRIEFS

The Department of Agriculture has recently transferred to the National Museum the large Venturi herbarium, containing about 16,000 specimens representative of slightly more than 10,000 members. The material was collected chiefly in the provinces of Tucuman and Salta, in north-central Argentina, and had been assembled by the late Prof. S. VENTURI over a period of about 15 years.

An inaugural banquet of the Smith-Reed-Russell Society of the School of Medicine, The George Washington University, was held at the University Club on the evening of January 13. Guest speakers included Dr. THEOBALD SMITH and Dr. FREDERICK F. RUSSELL, two of the three scientists in honor of whom the society is named. Other speakers included the President of the University, CLOYD H. MARVIN and Colonel ALBERT E. TRUBY, who received the key of the society for WALTER REED to transmit to Colonel WALTER L. REED, surviving son.

"Western American Alpines," a new book by IRA N. GABRIELSON, the Biological Survey's supervisor of predatory-animal and rodent control in the Pacific Region, has been published by The Macmillan Company.

The Washington Section of the Society of American Foresters met at the Cosmos Club on Thursday, January 12. JAMES W. GIRARD, Senior Logging Engineer, spoke on "The Forest Survey of the U. S. Forest Service."

PERSONAL ITEMS

Mr. E. C. CRITTENDEN, Chief of the Electrical Division of the Bureau of Standards, sailed on January 13 to attend the third biennial meeting of the Advisory Committee on Electricity and Photometry established by the International Committee on Weights and Measures. The meeting begins on January 31 at the International Bureau of Weights and Measures, at Sevres, just outside of Paris.

Mr. EARL HANSON, observer of the Department of Terrestrial Magnetism, who has been making magnetic observations at repeat stations in various South American countries since August, 1931, having completed his field work was en route for New York early in January. After a brief vacation in

that city, he will report at Washington for comparing his instruments and closing up his work.

PAUL E. HOWE, chemist, in charge of nutritional work, Bureau of Animal Industry was elected president of the Chemical Society of Washington at its annual meeting. JAMES F. COUCH, specialist in toxicology at the same bureau, was selected as one of its managers for the ensuing year. Other officers elected were: JAMES H. HIBBEN, secretary; ORVILLE E. MAY, treasurer; H. T. HERRICK, H. G. KNIGHT, E. W. WASHBURN, E. WICHERS, R. E. BIGSON and M. X. SULLIVAN, councilors; and J. A. AMBLER, N. BEEKEDAL, R. E. GILCHRIST, A. T. MCPHERSON and A. R. MERZ, managers.

Obituary

Professor HARLAN WILBUR FISK, magnetician and chief of the Section of Land Magnetic Survey, Department of Terrestrial Magnetism, Carnegie Institution of Washington, died at the Washington Sanitarium, Takoma Park, Maryland, on December 26, 1932, after a brief illness. Professor FISK was born at Geneva, Kansas, September 25, 1869, and was educated at Carleton College, Northfield, Minn. From 1899–1906 he held the professorship of mathematics at Fargo College (North Dakota) and was dean of the faculty from 1904–1906. In October 1906 he joined the staff of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington as magnetic observer. He made two detailed magnetic surveys of the Bermuda Islands in 1907 and 1922, respectively, and led a magnetic-survey expedition to British, Dutch, and French Guiana in 1908. He also took part in various expeditions sent out by the Department to investigate possible effects on the Earth's magnetism due to solar eclipses, the most recent of these being the total solar eclipse of last August when he was in charge of the three parties sent to New England by the Department for this purpose. During the last few years he has been engaged in important researches on the secular variation of the Earth's magnetism based largely on data obtained under his supervision by observers of the Department of Terrestrial Magnetism. Professor FISK was a member of a number of scientific bodies including the Washington Academy of Sciences, and the Philosophical Society of Washington. He was also an active member of the American Geophysical Union being secretary of its Section of Terrestrial Magnetism and Electricity for the period 1929–1932.

ERNEST HOWE, geologist and editor of the American Journal of Science, died suddenly Dec. 18, 1932, at his home in Litchfield, Conn. He was born in New York City Sept. 28, 1875, and graduated from Yale University in 1898. From Harvard he received the degree of Ph.D. in 1901. He was a member of the U. S. Geological Survey from 1898 to 1908, and in 1906 and 1907 he was the geologist of the Isthmian Canal Commission. Between 1908

and 1926 he spent much of his time as a consulting geologist in the Grass Valley gold field of California. From 1926 until his death he has edited the American Journal of Science. Among Dr. HOWE's best-known publications are his reports on the gold deposits of Grass Valley, California, and the landslides of the San Juan Mountains of Colorado.

Dr. THEODOR HOLM, research professor of botany at the Catholic University of America, died suddenly on December 26. Dr. HOLM was born at Copenhagen, February 3, 1854, and was educated at the University in his native city and graduated in 1880. He was made botanist and zoologist of the Danish North Pole Expedition and spent the next two winters in the ice packs of the Arctic Ocean. He spent the summers of 1884–1886 in West Greenland as botanist and zoologist for the Danish Government. In 1888 he came to the United States and five years later was a naturalized citizen. He explored the high alpine flora of Colorado from 1896 to 1899, and for eight years was botanical assistant at the Smithsonian Institution and the Department of Agriculture at Washington, D.C. Dr. HOLM was the author of many papers on taxonomy, morphology and anatomy, medicinal plants and arctic plants. At the time of his death he was working on morphological problems, and his researches were being published as they were completed in the *Botanisches Centralblatt.*

ANNOUNCEMENTS OF MEETINGS

The ACADEMY announces a meeting on February 16. *Program:* L. H. ADAMS.—*The basic concept of the physical sciences* (illustrated). This is the address of the retiring president.

The Philosophical Society announces the following programs:

February 25. Professor F. D. MURNAGHAN (Johns Hopkins University.—*The expanding universe.*

March 11. The third Joseph Henry Lecture. President K. T. COMPTON (Massachusetts Institute of Technology).—*High voltage.*

ADVANCE SUMMARIES

Hereafter the JOURNAL will accept for publication, in addition to original articles and proceedings, short summaries presenting the results of completed research projects. By these advance summaries, prepared by the investigators, the JOURNAL hopes to make current, in advance of final and full publication, the findings of local scientists. These summaries will take the form of regular articles but preferably should not exceed one page in length.

The programs of the meetings of the affiliated societies will appear on this page if sent to the editors by the tenth of each month.